The Engineer

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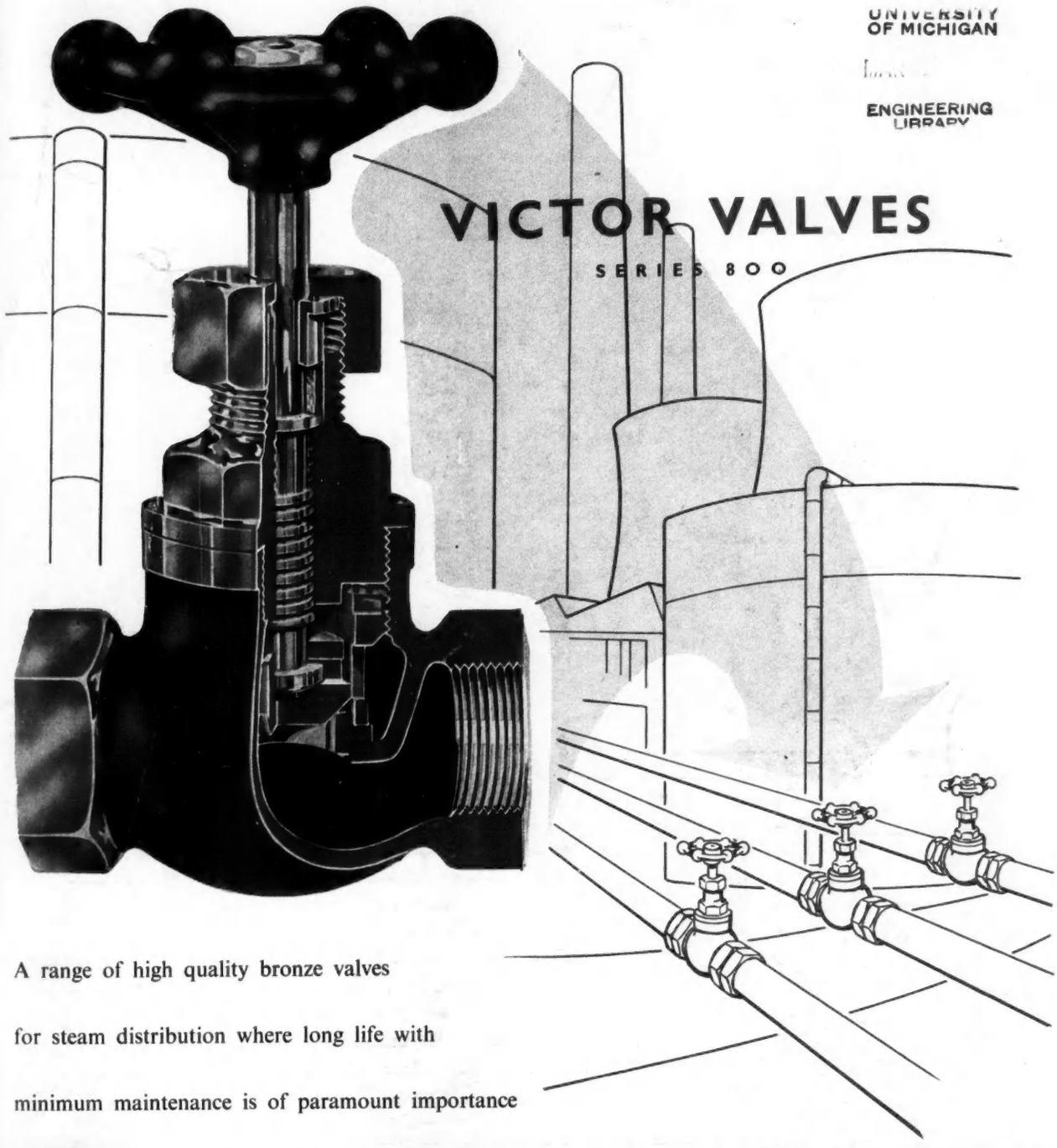

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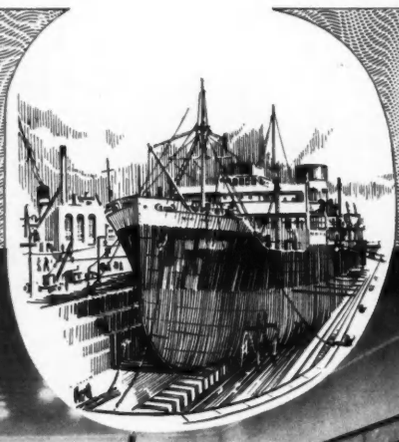

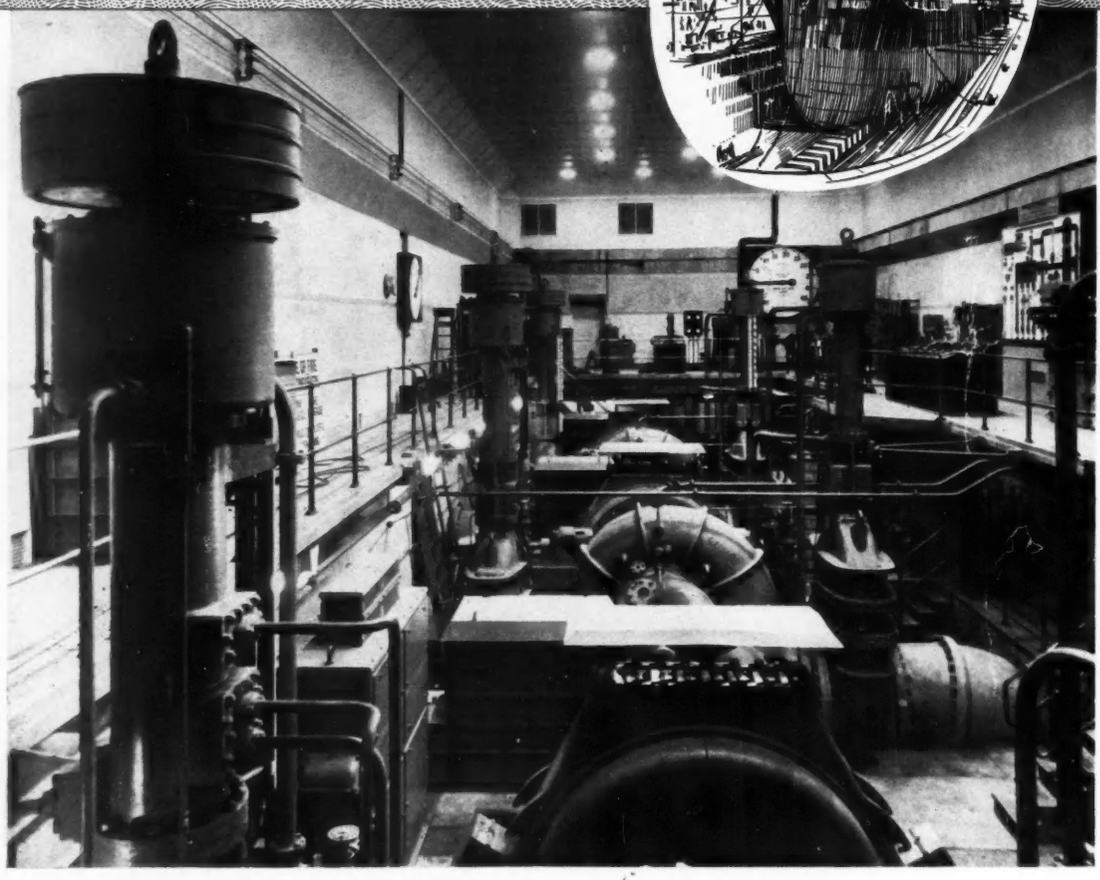

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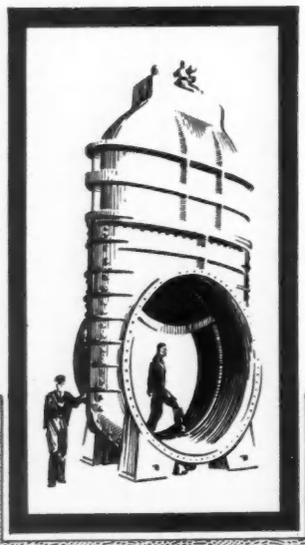

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THE ENGINEER

VOL. 203 No. 5276 MARCH 8, 1957

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MONOPOLY IN THE ELECTRICAL INDUSTRY?

An editor's life is often a hard one. How many people other than editors, we wonder, will think it necessary really to read the report of the Monopolies and Restrictive Practices Commission on the Supply and Exports of Electrical and Allied Machinery and Plant ? It runs, including the appendices, to 343 pages and, having read it, we felt forced to reach the firm opinion that there was no need to inflict upon the public such a spate of words ! The situation is made all the worse because only by reading the document can a firm assessment be reached about the relative strengths of the arguments of the industry and the arguments of the Commission. After reading the document it is certainly our impression that anyone unconnected either with the industry or with the Commission, will regard the Commission's main finding—that the common price systems maintained by the industry operate against the public interest—as "not proven." But as the document is so long and so indigestible it is unfortunately only too probable that the public will accept the Commission's findings without bothering to examine the grounds for them.

A purchaser is always suspicious of a ring which fixes the prices of the goods he wants to buy. It is always implied that the purpose of the ring is to exploit the purchaser for the benefit of an industry which wants to make fat profits without troubling unduly about the efficiency of its production methods or the adequacy of its productive resources to meet the true demand. But as this report very clearly reveals, the implication is by no means necessarily and always true. The electrical industry of this country comes out of the examination with clean hands. The industry may be mistaken in believing that its common price systems, by contributing to the industry's prosperity, contribute also to the public good. That is a matter of opinion ; and the opinion formed is likely to be coloured by preconceived notions about the desirability or the reverse of price competition in maintaining the energy and efficiency of individual firms. It is our impression that the opinions of the Commission have been so coloured. What is certain is that the industry has not deliberately held the customer up to ransom. True; there is some evidence that its profits have been on the high side. But the measurement is not easily made. For against what standards should the industry's profits be compared ; those of industry in general, coloured perhaps by the inclusion of industries experiencing a depression in demand ? Or of commerce besides industry ? Or only of selected engineering industries of more or less comparable character ? Any desired result can be obtained by making the right choice ! And is it not essential in an industry that has been and continues energetically to increase its productive capacity and improve the technical merit of its products that profits should be on the high side so that capital is available to plough back and investment is attractive to the public ? Possibly prices are so fixed that high cost producers can still operate without making losses. The point is difficult to determine because of the complexity of the industry and because the modernisation of the productive methods of particular departments in a large firm is not necessarily kept in step. But is it so terrible in an expanding industry that out of date plant or methods should still be able to yield a modest profit ? In the iron and steel industry which has been energetically expanding output ever since the war, prices are so fixed that obsolescent plant can still more or less cover its costs of production. Even the C.E.A. fixes its prices for electricity in such a way that the operation of plant, obsolescent and due to be renewed as soon as possible, does

not cause the accounts to show a deficit. When demand is high and increasing it is very desirable to keep marginal capacity profitable; and even when there is a check to the demand, so long as it be only temporary, it is desirable to ensure the survival of the marginal capacity. Undoubtedly the organisation of a price ring can be very objectionable; particularly so when allied to restrictions upon output and the calculation of quotas. But the electrical industry has set its face against such practices; and there is certain weight in its contention that the fixing of common prices encourages purchasers to choose on the basis of quality. If competition by price is ruled out there is every inducement in an expanding industry to firms not only to improve the quality of their products but to find also efficient means of producing them so that their profits shall be higher, their ability to expand greater, and their research work unhampered by lack of expensive equipment.

Of course, the fixing of common prices is sometimes irritating to customers. But in so far as exports are concerned surely the industry can be left to look after its own affairs. There is plenty of competition abroad and if the irritation leads to the loss of orders no doubt the industry will take action to relieve the situation. As for the Central Electricity Authority, which appears equally irritated, we cannot really feel very much sympathy for it. It is so powerful a customer that the industry must necessarily feel a need to be organised in face of it—all the more so that the Authority seems to have been trying, not without success, to break the price ring. It is highly improbable that the Authority and the industry will ever see eye to eye. But the power seems nicely balanced as it is. Under constant pressure from the Authority and remembering that the Authority has power to purchase abroad, it seems to us very unlikely that the industry could relapse into inefficiency, particularly when it is realised that the price "ring" is not wholly closed. Before any action is taken to compel the industry to comply with the report of the Commission—fortunately it cannot be taken at once—we implore all concerned to read the report with open minds. We think it unlikely that they will fully agree with the Commission though it is possible they may conclude that the advantages to the industry of the price fixing arrangements are less high than the industry itself deems them to be. It is quite clear from an appendix in the report that if it was really convinced that any of its practices were not in the public interest the industry would be willing to amend them. It is along those lines that further action should be taken. For, if it is true—we confess to a doubt of it—that the prosperity of the industry is really dependent upon the maintenance of its common price systems, it would be ridiculous to break up the system merely to satisfy a prejudice against price rings.

DEFENCE OR DETERRENT?

When replying to the recent Opposition motion calling for a revised defence policy, the Minister of Defence could not, and did not, anticipate the forthcoming White Paper. But he made it clear at the outset that drastic economies in defence expenditure could not be achieved overnight. "My task," he said, "is to reshape our Armed Forces, not to mutilate them." This indeed has been the task of a succession of Defence Ministers ever since, two years ago, the White Paper informed us of the appalling effects of the thermo-nuclear bomb. Meanwhile, there has been no firm indication from the Government of the kind of reshaping it has in mind, apart from giving first priority to nuclear and thermo-nuclear missiles and the means of delivering them. But it has also attached great importance to conventional forces. Not only were the cold and limited wars the more immediate and more likely danger. In a global war the NATO Powers had to hold the line by land, sea and air until the nuclear counter offensive had broken the back of the enemy assault. We could not, in fact, rely on strategic air power alone. We had also to demonstrate that we had both the will to survive and the power to ensure victory. These two requirements—the offensive and the defensive—have thus inevitably led to hesitation and delay—how much to spend on new and how much on conventional weapons? Now, at last, a decision is essential because of the financial situation. We cannot be strong everywhere—what can we throw overboard?

There is no doubt whatever that among the NATO Powers, Britain is bearing more than her fair share of conventional forces, and Mr. Sandys was right in emphasising that we can no longer afford to do so and must review the size of the Forces we could reasonably maintain on the Continent of Europe. But he was on more debatable ground in holding that we must now concentrate our military effort on prevention rather than on defence because of the present superiority of the means of attack. This is the view held generally in the Royal Air Force, though the emphasis is on the "offensive" rather than on "prevention." Despite guided missiles with nuclear warheads, so the argument runs, it is virtually impossible to prevent some bombers getting through; half a dozen could, in a single raid, cause incalculable death and devastation over enormous areas. All that matters, therefore, is that we should have the power to retaliate. That is why fighters are required—to protect our bomber runways, not the British Isles as a whole, though from what existing prototypes satisfactory supersonic fighters are to be developed it is not easy to see. We cannot agree with this view, which, incidentally, does not accord with the determination shown by our people in 1940 to endure the worst that could befall them. In a global war the Russians would have many important targets and no more than a part of their bomber force could be spared for use against Britain—certainly not a large enough part to make fighter and guided missile defence a worthless attempt to achieve the impossible. Of course, Soviet bombers are not the only danger. There is every reason to believe that the Soviets already have intermediate range ballistic rockets capable of reaching this country from territories which they control. Against these rockets there is at the present time no defence. But the United States Army authorities are known to be working on an "anti-missile missile" which, they claim, should be able to deal with them; and though the technical problems of interception are highly complex, there is no reason to suppose them utterly insoluble.

A defence policy which is successful in preventing war is, of course, the ideal. But prevention should be divorced from any question of prestige. For the next ten years, while the bomber remains the principal long-distance explosive carrier, the deterrent already exists in adequate measure in the massive United States Strategic Air Force. Britain, we feel, should use these intervening years to prepare for the future, meanwhile doing the best within her limited resources to meet NATO's most urgent requirement—the survival of Britain as a base in the event of war. One possibility worthy of study is that we should adapt our older carriers—before they are all sold to other countries!—and other suitable large ships for launching ballistic rockets with a range of 1000 miles. Rockets with about this range will soon be in production in the United States and could and should be made available to us under Mutual Aid. When the financial situation improves, we should also build more ships of 20,000 tons to supplement the older vessels. All these ships could be at sea before the outbreak of a war. Our retaliatory power would, in fact, be afloat and relatively safe in war, with the Royal Navy in peace time—with or without our allies—reverting to its true and historical role of preserving the peace of the world. This does not mean sacrificing all we have done hitherto in building up our retaliatory power for the purposes of prestige. We already have a sufficient number of bombers for the stocks of nuclear and thermo-nuclear bombs now available. But let us in future act in the best interests of NATO by earmarking further production of fissile material for the warheads of anti-aircraft guided missiles and other tactical weapons.

A Seven Day Journal

Great Britain's 6000MW Nuclear Power Programme

A THREEFOLD expansion of the first nuclear power programme outlined in the White Paper of February, 1955, was announced on Tuesday last, in the House of Lords, by the Minister of Power, Lord Mills, and in the House of Commons by the Paymaster-General, Mr. Reginald Maudling. Lord Mills said that, in the light of present knowledge, the English and Scottish Electricity Authorities could reasonably aim at having at least 5000MW of nuclear power capacity in operation by the end of 1965 and that, if technological development continued to be favourable and the necessary physical and financial resources could be found, a figure of 6000MW could be achieved by that date. Accordingly, it had been decided to adopt, as the basis for present planning, a range of 5000–6000MW nuclear capacity in operation by the end of 1965. The supply of raw materials, the acquisition of sites and the planning of the transmission network, would be on a requisite scale. Lord Mills also said that the Electricity Board for Northern Ireland intended to bring into commission a 150MW nuclear station in 1963 or 1964. At a Press conference last Tuesday, Lord Mills explained that the revised nuclear power programme would involve a capital expenditure of £750 million more than would be required if the equivalent capacity were to be provided by conventional generating stations; on the other hand, a full year's operation of 6000MW nuclear generating would save about 18,000,000 tons of coal annually. Lord Mills confirmed that the new nuclear power programme would be phased to allow for the manufacture and export of nuclear power plant. In reply to a question at the Press conference, Lord Citrine, the chairman of the Central Electricity Authority, gave an estimate of the possible size of some of the nineteen stations envisaged in the new programme. Recalling that the guaranteed outputs of the first two stations were stated by the manufacturers to be 300MW for Bradwell and 275MW for Berkeley, he said that stations started in eighteen months' time might possibly be designed for an output of 500MW, when completed. Lord Citrine estimated that, by 1965, nuclear power stations might constitute about 15 per cent of Great Britain's total generating capacity. The electricity output from these stations operating as base load plants would, however, represent about 25 per cent of the country's total.

Institution of Electrical Engineers

NEARLY 1500 members and guests of the Institution of Electrical Engineers attended the Institution's annual dinner at the Grosvenor House, London, on February 28. After the loyal toast, the president of the Institution, Sir Gordon Radley, announced that by a happy coincidence the dinner was being held on the ninety-ninth birthday of Sir James Swinburne, who was the oldest living past-president (1902). With the assent of the assembled company, a greetings telegram was sent to Sir James. The toast of "The Institution" was proposed by Sir Oliver Franks, who spoke of the present world of tensions existing between five continents, with five major capitals, five social systems, all with separate and, often, conflicting outlooks. Half a century ago there were fewer capitals and the processes of political growth and adjustment were comparatively gradual. After two world wars, changes and adjustments tended to be sudden and sometimes violent: for example, the emergence of India, Pakistan and Ceylon as independent states in 1947 and the Suez crisis in 1956. The long period of comparative stability enjoyed by the Middle East, under British influence, had given place to a situation in which the U.S.A. and the U.S.S.R. now faced each other across the Middle East, with increased possibilities of tension. But although the world no longer looked to Britain for political guidance, British engineers had an important part to play in raising standards of living and improving means of communication. Sir Gordon Radley, who replied to the toast, spoke of the need for boldness in British engineering to offset the great numerical advantage possessed by the U.S.A. and the U.S.S.R. Some risks had been taken in the joint Anglo-American venture which established the first transatlantic telephone cable. Similar risks had been taken by Great Britain in building Calder Hall, which set the pattern for the first decade of nuclear power development in this country. Engineers should be aware of the urgency of the task of equipping industry to produce the material wealth upon which Great Britain depended. The toast of "The Guests" was proposed by Sir George Nelson, Bt., and Dr. Charles Hill, M.P., Chancellor of the Duchy of Lancaster, responded.

The Engineer
100 Years Ago
(MARCH 6, 1857)

"SKILLED WORKMEN"

"SIR,—The want of skilled workmen having occupied your attention, and your correspondents having given a solution at variance with the common practice of the workshops, I will venture to encroach upon your space by giving my experience in some of the largest engineering establishments in Great Britain, in which I have noticed that the dearth of good workmen in all branches is in proportion to the absence of a proper system for the division of labour, coupled with the total disregard paid to the tuition of the youths who the masters agree to take and teach the *trade*; no sooner is the boy in the shop than he is put to and kept at the kind of work he is most useful at—not in a direct manner by the masters, but indirectly by sounding some such stimulant as the following in the ears of the foreman:—'Your department is costing too much; cannot you have boys or commoner men for the commoner work?' The foreman, having no interest in the progress of the apprentices in good keeping with his own situation, places and keeps the youths at that class of work he can produce the most of.... The masters find it more to their advantage to have boys and teach them one particular class of work, paying them accordingly, than agreeing to teach so many branches, and the apprentice being made master of none.

"Now, Sir, to remedy this want of skill, I would place every apprentice or boy in the hands of the foreman of that department, holding him responsible for their proper tuition in any branch of his department, and remunerate the foreman according to the instruction to be given. And I would also have a day for examination of apprentices triennially, and award prizes to each youth that produced the best specimen of work.... But a better education is absolutely necessary, to assist which I would beg to solicit every master to insist upon the parents of each youth in his employment, being sent, at certain hours, to school, which can be easily done and at a trifling cost.—A WORKMAN."

Planning Hong Kong Airport

THE problems of siting and planning a modern airport suitable for operation of the large jet airliners which will come into operation in a few years' time, are necessarily complex, even when the topography is favourable. At Hong Kong, the topographical problem also was one of some difficulty. The work of investigating several possible sites, and the design ultimately chosen on the selected site were described at the Institution of Civil Engineers on February 26, when the paper "The Planning and Design of the New Hong Kong Airport," by Messrs. H. Grace and J. K. M. Henry, was presented for discussion. The new airport, which is at present under construction, will consist of a single runway, over 8000ft in length, largely on reclaimed land built as a promontory extending out to the harbour. One approach to the runway will be a straight-instrument approach from the sea, but the other involves a 40 deg. turn to avoid mountains, and about 1000ft of the runway will not be used on this approach. The final layout aims at as much economy as possible in the civil engineering works. Reclamation has been reduced to about 162 acres, dredging to about 10,000,000 cubic yards, and the length of sea wall to be built to about 5400 yards. About 3,000,000 cubic yards of excavation is also needed to remove hills. The overall cost of this work, including building and ancillary works, is estimated to be about £7,000,000, and the construction time four years, though the runway will be put into use after three years of work. Construction started in 1955, the consulting engineers being Messrs. Scott and Wilson, Kirkpatrick and Partners, Hong Kong, and the main contractor the Société Française d'Entreprises de Dragages et de Travaux Publics.

Major R. H. Mayo

WE record with regret the death, on Tuesday last week, of Major Robert Hobart Mayo, O.B.E., M.A., F.R.Ae.S., aged 66. After taking both mathematical and mechanical sciences tripos, Mayo entered the Royal Aircraft Factory before the 1914-18 war, during which he served with the Royal Flying Corps in France and at the Air Ministry. He subsequently became a consulting engineer, and in 1935 formed a company to exploit the composite aircraft he patented. This overcame the problem of taking off an aircraft capable of carrying an economic load over long ranges by uniting with a less heavily loaded aircraft for the initial stages of the flight. An example was built for the ambitious task of carrying 1000 lb of mail across the North Atlantic against head winds: cruising at 182 m.p.h., an endurance of 21·5 hours was needed. The long range aircraft took the form of a float seaplane with four Napier "Rapier" H-16 air-cooled engines, and rode above a flying boat with four Bristol "Pegasus" engines that was essentially similar to the Short "Empire" liner. The two were named "Mercury" and "Maia" respectively. The flight of "Mercury" to Montreal in July, 1938, was the first occasion on which a commercial load had been flown across the Atlantic. Later that year a flight from Dundee to the Orange River established a seaplane distance record of 5997 miles which still stands.

Investigation of a Vortex Air Cleaner

By T. C. DANIELS, M.Sc., A.M.I.Mech.E.*

The main problem of air or gas cleaning is the economical removal of dust particles below 20 microns (25·4 microns=1 thousandth of an inch). The conventional vortex air cleaner is the cyclone, in which the dust-laden air is fed tangentially into a cylindrical casing. The dust particles are subjected to a centrifugal force which will cause the particles to drift to the casing wall, and hence fall into the dust collector, whilst the low pressure core of cleaned air rises out of the cyclone. The efficiency of dust separation of the cyclone falls off rapidly for dust particles below 20 microns. This is probably due to the reversal of the air flow in the cyclone setting up secondary air flows which re-entrain the finer dust particles. The investigation described was concerned with a straight through flow vortex air cleaner with the following objects in view. First, to find if re-entrainment of the finer particles is the reason for the drop in separating efficiency at about 15 microns for current cyclone cleaners. Secondly, to find whether the finer particles reach the separating wall of the cleaner within a definite separating length of vortex tube, and are afterwards re-entrained. Thirdly, to find a method of removing the finer particles provided they reached the separating wall. The investigation established that there was an optimum separating length of the vortex tube and that there was re-entrainment of the small particles after reaching the walls of the vortex tube. Further, a method of removal of the finer particles on reaching the walls of the vortex tube was found to be successful and, within limits, this method may have commercial value.

ASHMAN (1952) and Davies (1952) give an up-to-date picture of the various kinds of air and gas cleaners and their inherent problems and limitations. The author, therefore, does not propose to give any background to this investigation, but to give a brief outline of theory, experimental procedure, discussion of results obtained and the conclusions that can be inferred.

Theory of Vortex Air Cleaning

Consider the two following cases of gravitational and accelerated sedimentation of particles in a stream of gas or air. Fig. 1 shows an air stream in which a large and a small particle are allowed to settle through a

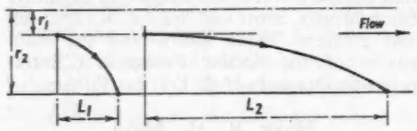


Fig. 1—Gravitational sedimentation in a stream

height r_2-r_1. Obviously, the longer separating length L_2 will be that for the small particle, and the reason for this is the smaller terminal velocity (Stokes Law of Sedimentation) and, therefore, a longer time in suspension. Fig. 2 shows a rotating air stream in which a large and small particle are allowed to drift from a radius r_1 to radius r_2. The larger particle will have a much shorter separating length L_1, as compared with L_2 for the small particle. The particles move down an expanding helix and have three components of velocity: (i) the tangential swirl velocity; (ii) the drift velocity which is at right angles to the swirl velocity and in the same plane; (iii) the axial flow velocity in the general direction of flow.

In a paper by Umney (1948) a mathematical analysis of this accelerated sedimentation is given. Referring to Fig. 3, a particle P is moving from A to B in a free vortex defined by $V_w \cdot r = X$=constant. The equations of motion of the particle in equilibrium between the forces of acceleration and drag are

(radial direction)

$$-mK\frac{dr}{dt}=m\left[\frac{d_2r}{dt^2}-r\left(\frac{d\theta}{dt}\right)^2\right]$$

$$\frac{d_2r}{dt^2}+K\frac{dr}{dt}-r\left(\frac{d\theta}{dt}\right)^2=0 \quad . \quad . \quad (i)$$

(tangential direction)

$$-mK\left[\frac{rd\theta}{dt}-V_w\right]=m\left[\frac{rd_2\theta}{dt^2}+2\frac{dr}{dt}\cdot\frac{d\theta}{dt}\right]$$

$$\frac{2}{r}\frac{dr}{dt}\cdot\frac{d\theta}{dt}+\frac{d_2\theta}{dt^2}+K\left[\frac{d\theta}{dt}-\frac{X}{r^2}\right]=0 \quad . \quad . \quad . \quad (i)$$

K is the drag/unit relative velocity/unit mass.

Equations (i) and (ii) are rendered dimensionless by substituting for the radius r in terms of $\frac{R}{\sqrt{K/X}}$ and time t in terms $\frac{T}{K}$; R and T being dimensionless variables of radius and time. Equation (i) in dimensionless form then reduces to

$$\frac{d_2R}{dT^2}+\frac{dR}{dT}-\frac{1}{R^3}[1-e^{-T}]^2=0$$

$r=\frac{R}{\sqrt{K/X}}$ $t=\frac{T}{K}$ $V \cdot r_1=V_w \cdot r=X$ free vortex condition.

K is the drag/unit relative velocity/unit mass and in terms of diameter of particle, viscosity of air, and the densities of the particle and air, respectively, $K=8\cdot63\times10^{11}\frac{\rho}{\rho^1}\frac{\nu}{d^2}\text{sec}^{-1}$

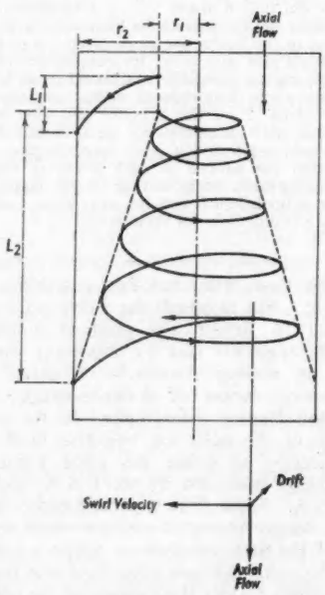


Fig. 2—Accelerated sedimentation in a rotating stream

ν=kinematic viscosity, square foot per second.
d=particle diameter, microns.
ρ=density of air, slugs per cubic foot.
ρ_1=specific gravity of particle, grammes per cubic centimetre.

The above dimensionless equation was solved by means of a differential analyser, giving values for the non-dimensional T term for the particle to move from an inside radius to an outside radius of the free vortex, this T term being converted back into t seconds.

Using the following values of constants listed below, the time taken by a specific particle to drift from one radius to another can be found, and hence this time multiplied by the mean axial velocity will give the separating length of the vortex tube. The constants taken were[1] $V_w \cdot r = X = 500$ velocity in inches per second, and radius in inches; specific gravity of dust=2·7; kinematic viscosity of air at 60 deg. Fah. $=1\cdot56\times10^{-4}$ square feet per second; density of air slugs per cubic foot at 60 deg. Fah. and 14·7 lb per square inch=0·00237. Radius ratio

$$\frac{r_2}{r_1}=\frac{\text{radius of vortex tube}}{\text{radius at point of entry of particle into the vortex tube}}=2\cdot3$$

Mean axial velocity 40ft per second equivalent to 2500 cubic feet per hour of air at 14·7 lb per square inch, 60 deg. Fah.

Particle diameter, microns	Optimum separating length, inches
3	35·6
5	11·5
10	3·47

It is desirable to point out that these optimum lengths tabulated above were calculated from a theory which assumed free vortex conditions. Obviously, in practice, friction will be reducing the intensity of swirl down the vortex tube and eventually the separating force will become non-existent. For example, it was found that for a vortex tube, 2in inside diameter, that the swirl intensity had decreased appreciably at the end of the vortex tube for lengths greater than 9·5in and mean air flow of 3000 cubic feet per hour. An approximate solution to Umney's equation may be obtained by neglecting the second differential

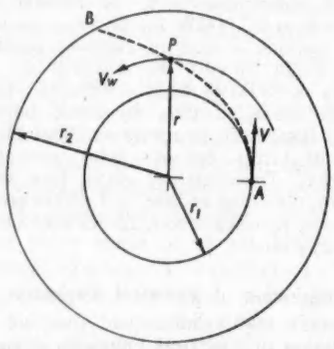


Fig. 3—A particle P moves from A to B in a free vortex defined by $V_w \cdot r = X$ (constant)

and the e^{-T} terms, as the time interval for the drift from one radius to another is a small fraction of a second.

Thus, the equation becomes

$$\frac{dR}{dT}=\frac{1}{R^3}$$

and integrates to

$$\tfrac{1}{4}[R^4_2-R^4_1]=T_2-T_1$$

Time interval

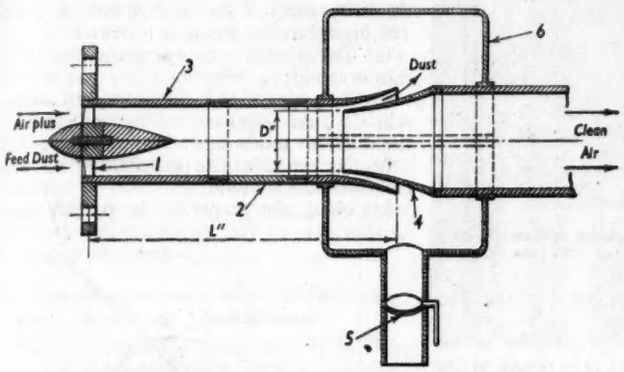
$$t=\tfrac{1}{4}\frac{K}{X^2}[r^4_2-r^4_1]$$

* Lecturer in Engineering at the University College of Swansea.

$r_2 = 1$in, $r_1 = \frac{7}{16}$in. $(r_2 - r_1)$ is the height of the blades producing the swirl, and K and X are evaluated from the constants as above. For a mean axial velocity of 40ft per second the equation of the approximate solution above will give the following values

Particle diameter, microns	Optimum separating length, inches
3	26·8
5	8·8
10	2·4

It was found in practice that the best separating efficiency of this vortex cleaner was given by a vortex tube of length 9·5in, an increase in length beyond this gave poorer separating efficiency, showing that the swirl intensity was decreasing more rapidly beyond this optimum length. Comparing this with the optimum separating lengths in the above table, it is obvious that particles below 5 microns will not be separated with high efficiency. With higher values of air velocities there will be a better chance of separating a large quantity of the finer dusts, but there will be an increased tendency for the larger particles to rebound off the wall and they will, therefore, disturb the slower separating drift of the finer particles.



1—Stator blades.
2—Extension piece.
3—Vortex tube of length L'.
4—Exit cone of diameter D'.
5—Butterfly valve.
6—Dust collector.

Fig. 4—Cross section of the vortex air cleaner

Description of Air Cleaner Test Rig and Method of Testing

Fig. 4 shows a cross section of the apparatus used. A vortex air cleaner with stator blades produces an air swirl. The dust-laden air, as it passes these stator blades, experiences a considerable centrifugal force of several hundred g. The heavier dust is then thrown on to the wall of the vortex tube, and the lighter fractions drift more slowly there. The dust therefore concentrates in the layer of air next to the wall, and this layer is bled off into the dust collector, via the annular space around the exit cone. This form of cleaner has several advantages over the cyclone. The straight through flow will give a lower pressure drop. There is no mixing of cleaned air with the dust-laden air entering the cleaner and as there is no reversal of flow (no secondary flows will be set up) this should eliminate one likely cause of re-entrainment of the dust particles.

The initial phase of the investigation concerned the angle of the stator blades which produced the centrifugal force. The angle is that between the chord of the blade and axis of the vortex tube. Fig. 2, earlier, gives the three components of velocity of a particle moving in an expanding helix. An increase in this blade angle will give a greater swirl velocity and hence a greater centrifugal force, which in turn will give a greater value of drift velocity. Increase in the latter will give better separation, i.e. higher mass efficiency. There will be a limit to the extent to which this angle can be increased, as the greater the angle the greater the pressure drop across the cleaner, because any increase in the swirl velocity produced by the blades will be accompanied by a pressure building up in the blades. The length of vortex tube was varied in conjunction with the blade angle, to see if the swirl produced by the blades decreased with length more rapidly for any particular blade angle.

Having established a blade angle the next phase concerned length of vortex tube and diameter of exit cone. A decrease in the latter increases the annular space through which bleed-off takes place of the concentrated dust layer on the vortex tube walls. In conjunction with this, the amount of air allowed to be bled off through the annular space was varied by the butterfly valve in the dust collector (see Fig. 4). This air bleed was varied from zero to a maximum of about 30 per cent of the total air flow, the mass efficiency being assessed for each percentage bleed-off. When the bleed-off is nil the layer of dust on the wall of the vortex tube will be moving under its own momentum into the dust collector. This phase of investigation led up to an optimum length and exit cone diameter. The air cleaner was then tested for intrinsic efficiency with a standard test dust for two air flow velocities.

There are two efficiencies often quoted concerning air cleaners, they are

(1) The quantitative mass efficiency

$$= \frac{\text{Weight of dust collected by air cleaner}}{\text{Weight of dust fed into the air cleaner}}$$

(2) Intrinsic efficiency = efficiency of separation of each particle size, i.e. this efficiency gives the selective action of the cleaner.

Poor intrinsic efficiency at large particle sizes led to an investigation of the dust distribution down the axis of the vortex tube by photography. This showed evidence of the rebounding of the large particles off the walls of the vortex tube, and, hence, the poor intrinsic efficiency at large particle sizes.

The final phase concerned structural alteration of the air cleaner to eliminate this rebounding of the larger particles, and further dust distribution photographs were taken to prove this to be so. In conjunction an intrinsic efficiency test was carried out. A second method of eliminating this rebounding was adopted and proved to be very successful. A diagram of the test rig is shown in Fig. 5. The method of carrying out a test run on the air cleaner was as follows.

The air flow was measured by an orifice plate. Dust of a specified particle size was fed at a controlled rate from the conical dust feeder. The feeder had an adjustable needle valve in the apex and the dust flow was aided by vibration of the cone in the guides by an electrically driven eccentric. From experimental experience the needle valve could be set to give a predetermined dust concentration, i.e. m.g.m.'s of dust per cubic foot of air. The dust-laden air was fed into the cleaner and the separated dust collected in the dust collector. If air was allowed to bleed past the exit cone then the dust would be collected in a multi-layered silk bag attached below the butterfly valve.

The ratio of the weight of dust collected to the weight of dust fed is the mass efficiency of the cleaner, and from the particle size analysis of both collected and feed dusts the intrinsic efficiency may be calculated, as shown later in the investigation. The pressure drop across the cleaner could be read directly off the appropriate manometer. The swirling air flow had to pass through straightening vanes before the manometer reading of the pitot tube could be taken. This latter reading gave, with the appropriate constants, the air flow in the exit pipe. Any difference between this value and that measured at the air flow orifice gave the air bled past the exit cone. This would then enable a value of the percentage air loss through the dust collector to be calculated.

The particle size analysis of the dust was obtained by sieving and water sedimentation. The dust used in this investigation was a mixture of fine silica sand (99 per cent of which would pass through a 100-mesh B.S. sieve) and silica powder. The ratio of the two was found to be five of powder to one of sand by volume. This mixture gives the desired range of particle size analysis as specified in B.S.S. 20 : 1949. Silica dust was used to overcome the degradation of the dust in passing through the cleaner, i.e. the particles must not disintegrate into smaller particles during their passage through the cleaner, otherwise the particle size analysis of the collected dust will have little meaning when it is compared with the analysis of the feed dust. For consistency in results two or three samples of the same dust must be analysed.

Investigation to Find the Optimum Root Angle of the Stator Blades

The first phase of the investigation on the vortex air cleaner was to determine the effect of variation of the root angle of the stator blades with mass efficiency. The length of the vortex tube was also varied to see if the intensity of swirl decreased with increasing length of vortex tube. The particle

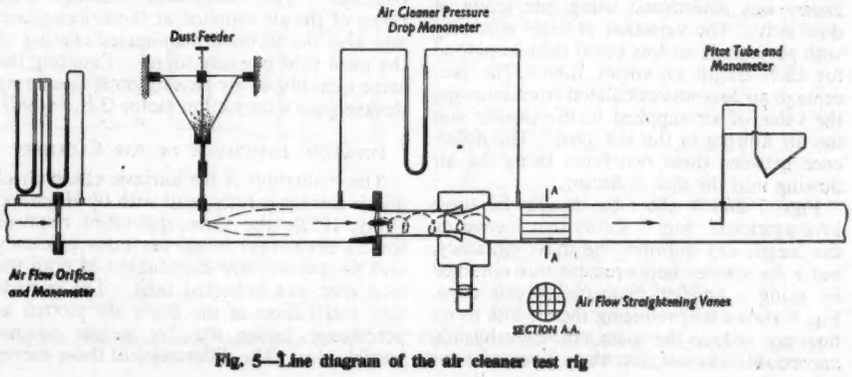


Fig. 5—Line diagram of the air cleaner test rig

size grading of dust used throughout this phase was, passing 100 B.S. sieve and on 150 B.S. sieve, i.e. particle size range<152 microns (μ)→> 104 microns (μ). The air flow was kept constant at 6100 cubic feet per hour (standard cubic feet at 14·7 lb per square inch, 60 deg. Fah.) within 1 per cent.

The inside diameter of vortex tube=2in; the exit cone diameter=1·875in; there were twelve blades in each stator of height 0·5625in ($\frac{9}{16}$in).

The results are plotted graphically on Fig. 6, from which it can be seen that the

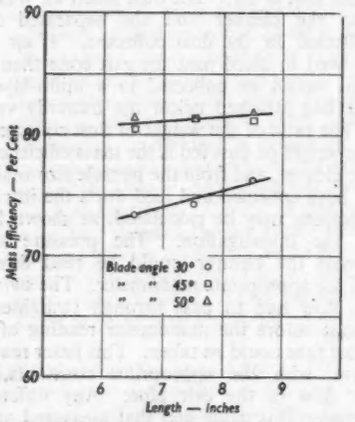


Fig. 6—Graph showing the variation of mass efficiency with the root angle of the stator blades

mass efficiencies for the 45 deg. and 50 deg. angle (i.e. angle between chord at root of blade and direction of air flow) are equally better than the mass efficiency of the 30 deg. angle. The 45 deg. angle was adopted for subsequent tests, as it was noticed that the pressure drop across the air cleaner increased from 7in to 7·5in water gauge for the 50 deg. angle blade. This is due to the increased pressure built up in the latter set of blades. The mass efficiencies for each set of blades remained virtually constant with increase in length of vortex tube, thus the intensity of swirl was not decreasing for vortex tube lengths up to 8·5in.

The second phase of the investigation was to find the following :

(*a*) The optimum length *L* of vortex tube and diameter *D* of exit cone (see Fig. 4 earlier) to give the maximum mass efficiency of the air cleaner. The length of the vortex tube was varied from 6·5in to 9·5in by inch intervals and for each length four grades of dust (each of increasing fineness) were used to assess the mass efficiency. This investigation was repeated for the three exit cones, each successive cone being of smaller diameter than its predecessor.

(*b*) In conjunction with the above, for each length of vortex tube the percentage air loss through the dust collector was varied from zero to a maximum. The mass efficiency was determined using one grade of dust only. The variation of mass efficiency with percentage air loss could then be plotted for each length of vortex tube. The percentage air loss was calculated from knowing the value of air supplied to the cleaner and the air flowing in the exit pipe. The difference between these two flows being the air flowing into the dust collector.

Figs. 7 and 8 show the results of these investigations. Fig. 7 shows that increasing the length did improve the mass efficiency, but a far greater improvement was obtained by using a smaller diameter of exit cone. Fig. 8 shows that reducing the air loss to nil does not reduce the mass efficiency by any appreciable amount, less than 2 per cent for

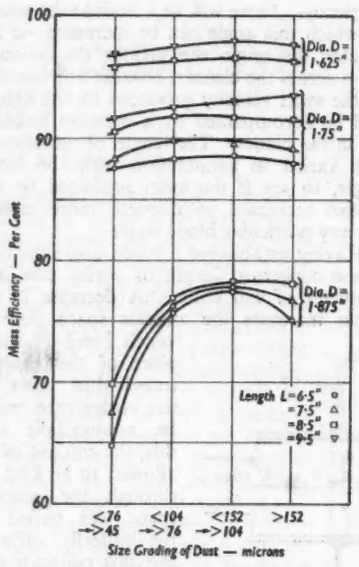


Fig. 7—Graph showing the variation of mass efficiency with length of vortex tube and exit cone diameter

the exit cones of diameters 1·75in and 1·625in.

For the measurement of air flow in the exit pipe by use of a pitot tube placed at the centre of the pipe (see Fig. 5) it was necessary to find the correction factor (C.F.) to multiply

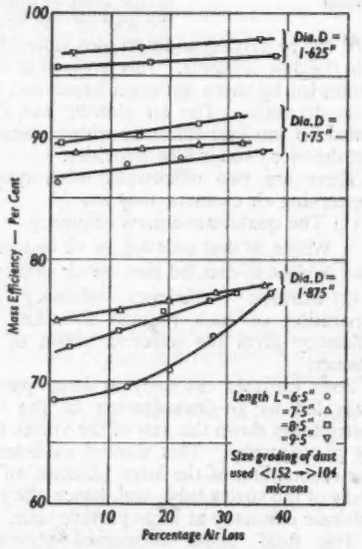


Fig. 8—Graph showing the variation of mass efficiency with the percentage air loss through the dust collector

the maximum air velocity in the exit pipe to give the mean velocity across the 3in diameter exit pipe. This was done by allowing no air to leak out of the air cleaner collection chamber. The manometer readings were taken of the air supplied at the orifice plate, and also the inclined manometer reading of the pitot tube is easily found. Equating the same quantity of air passing both measuring devices gave a correction factor C.F.=0·967.

Intrinsic Efficiency of Air Cleaners

The evaluation of the intrinsic efficiency of an air cleaner is fully dealt with by Heywood (May, 1952), the three quantities required for its evaluation being the mass efficiency and the particle size distribution of both the feed dust and collected dust. The particle size distribution of the dusts are plotted as percentage under size by weight against particle size. The differential of these curves gives the size frequency distribution. The mass efficiency adjusts the ordinates of the collected dust frequency curve; then the ratio of the ordinates of the two frequency curves for feed and collected dusts is the intrinsic efficiency, which can then be plotted for the whole range of particle size.

Investigation to Find the Intrinsic Efficiency of the Vortex Air Cleaner

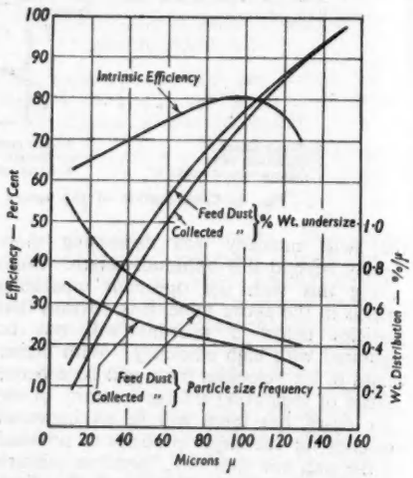
From the foregoing investigations the results indicated that the most efficient length of vortex tube was 9·5in and the highest mass efficiencies were given by the exit cone of outside diameter 1·625in. The air cleaner was now tested for intrinsic efficiency using a standard grade of dust. The procedure for this is as follows :

(*a*) The particle size distribution of feed dust is found;

(*b*) A sample of this dust is used to ascertain the mass efficiency of the air cleaner, the usual air measurements being taken;

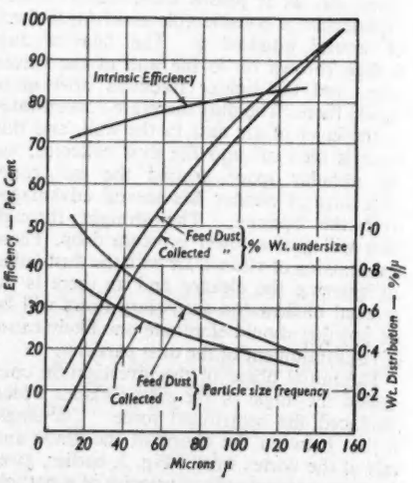
(*c*) The particle size distribution of the collected dust is found;

(*d*) Using the graph of the particle size


Intrinsic Efficiency
Feed Dust Collected " } % Wt. undersize
Feed Dust Collected " } Particle size frequency
Efficiency — Per Cent
Wt. Distribution — %/μ
Microns μ

Constants relative to the graphs are :
Air flow 4500 cubic feet per hour at standard temperature and pressure.
Dust density 41 m.g.m. per cubic foot of air.
Mean mass efficiency 69·25 per cent.
Pressure drop across air cleaner 6·5in water.

Fig. 9—Graph of the intrinsic efficiency for the air cleaner derived from graphs of the particle size distribution and graphs of particle size frequency of feed and collected dusts respectively


Intrinsic Efficiency
Feed Dust Collected " } % Wt. undersize
Feed Dust Collected " } Particle size frequency
Efficiency — Per Cent
Wt. Distribution — %/μ
Microns μ

Constants relative to the graphs are :
Air flow 2960 cubic feet per hour at standard temperature and pressure.
Dust density 45·5 m.g.m. per cubic foot of air.
Mean mass efficiency 71·2 per cent.
Pressure drop across air cleaner 2·6in water.

Fig. 10—Graph of the intrinsic efficiency for the air cleaner derived as in Fig. 9

distribution of feed and collected dust the intrinsic efficiency is calculated.

Two test runs were carried out, both of which were repeated to see how consistent the results would be. The first test run was made with an air flow of 4500 cubic feet per hour approximately, with the second run an air flow of 3000 cubic feet per hour. As can be seen from Figs. 9 and 10, the intrinsic efficiencies are almost the same. However, with the higher air flow (Fig. 9), it will be noticed that the intrinsic efficiency for particles greater than 100μ is falling and is lower than that for 3000 cubic feet per hour test run. A possible reason for this could be due to the larger and, hence, heavier, particles bouncing on and off the wall of the vortex tube, some of which would be carried away in the air stream taking with them some smaller particles.

Proof of this bouncing on the wall was obtained later by photographing the dust distribution along the axis of the vortex tube. The dust distribution was trapped on the glued flat surfaces of several glass rods spaced along the axis of the vortex tube, these rods were then photographed side by side with a projection microscope.

Photographing the Dust Distribution Inside the Vortex Tube

The accompanying diagrams (Fig. 11) show the 2mm glass rods with flat surfaces ground to the same depth and length. They were fitted into the wall of the vortex tube and equally spaced axially. It was desirable

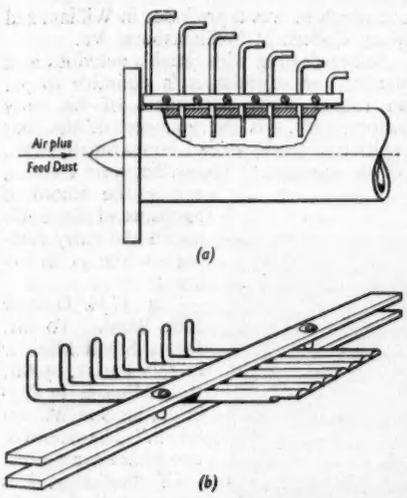


Fig. 11(*a*)—Vortex tube showing the glass rods with ground flat surfaces. (*b*)—The glass rods assembled for the microscope with ground surfaces facing downwards

that the thin film of glue should remain tacky in the air stream, and equal mixtures of butyl thylate and commercial "Durofix" were found satisfactory. For photographing the distribution a "Vickers" projection microscope was used, the rods being mounted together as shown. A magnification of seven was sufficient. The rods in the photographs were numbered in the direction of air flow. The ends of the rods could be seen at the base of each photograph. In all the tests which were photographed the dust used had a particle size range of less than 150 microns to greater than 45 microns.

In Fig. 12, the air flow was 3000 cubic feet per hour and the photograph shows a tendency for the dust to drift towards the wall of the vortex tube, but there is considerable evidence of bouncing of the larger particles over every rod. This latter characteristic is the reason for low intrinsic efficiencies of the larger sized particles, as shown in Figs. 9 and 10. As further proof of the rebounding of the larger particles, a scroll entry (see Fig. 14) was used to replace the stator blades, the length of tube being unaltered at 9·5in. The scroll entry leads the dust-laden air tangentially on to the wall of the tube, and the centrifugal force kept the dust on the wall until it reached the dust collector. In Fig. 13 the photograph shows a much improved drift of particles towards

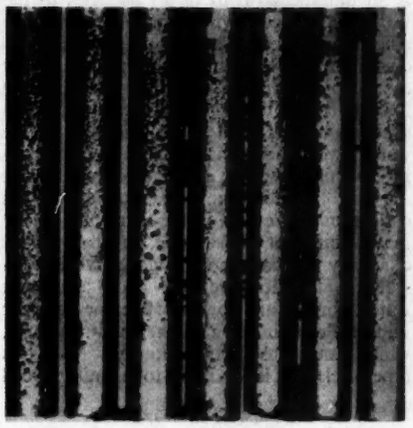


Fig. 12—Dust distribution down the axis of the vortex tube. The air flow was 3000 cubic feet per hour, equivalent to an axial velocity of 48ft per second from left to right. The dust used had a particle size of less than 150 microns to greater than 45 microns. As can be seen, there is considerable evidence of bouncing of the larger particles over every rod

Fig. 13—Dust distribution down the axis of the vortex tube, using a scroll entry, see Fig. 14, to replace the stator blades. The air velocity is from right to left and the particle sizes are the same as in Fig. 12. As can be seen, there is no evidence of rebounding of the larger particles and there is a much improved drift of all particles towards the wall of the vortex tube

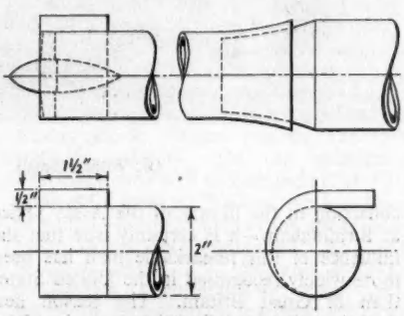
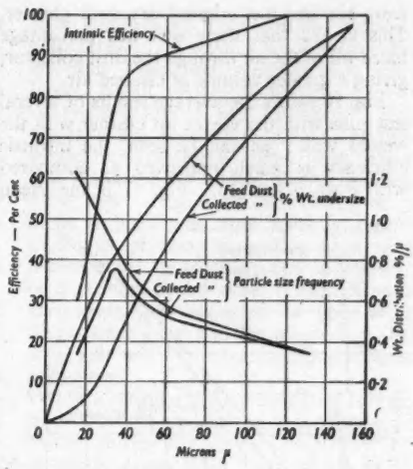


Fig. 14—The scroll entry replacement for the stator blades



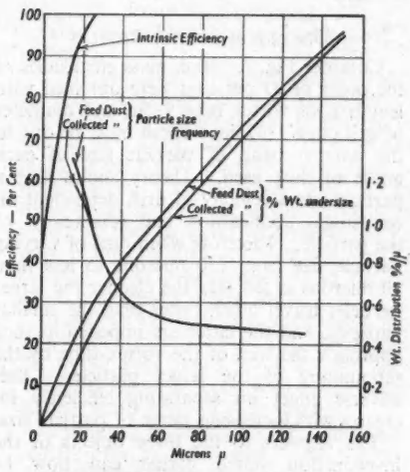
Constants relative to the graph are :
Air flow 3070 cubic feet per hour at 14·7 lb per square inch and 60 deg. Fah.
Dust density 41 m.g.m. per cubic foot of air.
Mean mass efficiency 68·3 per cent.
Pressure drop across air cleaner 2·4in water.

Fig. 15—Graph of intrinsic efficiency for the air cleaner with a scroll entry derived as in Fig. 9

the wall with little evidence of rebounding.

The intrinsic efficiency on Fig. 15 for the scroll entry shows much better classification.

A second method to eliminate this rebounding of the larger particles was investigated. The vortex air cleaner was used in its original form with the exception that four tangential jets of water immediately behind the stator blades gave a continuous wetted boundary layer. The particles of dust did not rebound from this wetted layer, and hence much improved mass and intrinsic efficiencies were obtained. A plus or minus variation of the separating length of the vortex tube showed that the original length of 9·5in gave the better intrinsic efficiency by a narrow margin. However, a decrease in blade height, i.e. a decrease in the radius ratio r_2/r_1 (reduction in blade height) mentioned earlier in the section on the theory of vortex cleaning, gave an increase from 91 per cent to 95 per cent in mass efficiency. This gave a slight increase in the intrinsic efficiency values for the smaller fractions of the dust spectrum. It was found that it was unnecessary to decrease the diameter of the exit cone for the wetted wall cleaner, the depth of the annular space being $\frac{1}{16}$in as compared

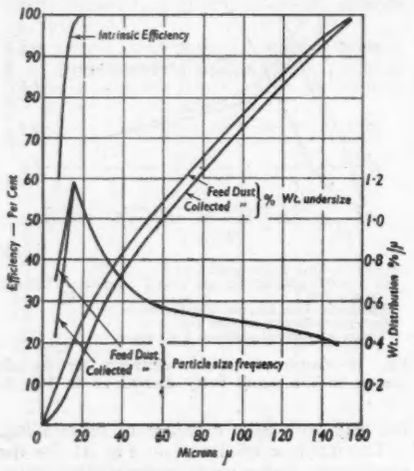


Constants relative to the graphs are :
Blade height $\frac{1}{16}$in.
Air flow 2980 cubic feet per hour at S.T.P.
Dust density 43·5 m.g.m. per cubic foot of air.
Mean mass efficiency 91·5 per cent.
Pressure drop across air cleaner 2·6in water.

Fig. 16—Graph of intrinsic efficiency of the air cleaner, using the wetted wall, derived as in Fig. 9

with ¼in for the original dry wall cleaner. This means that there was less percentage bleed-off of the air through the dust collector, giving a greater volume of cleaned air.

Fig. 16 shows the average results of several test runs with the vortex air cleaner with the wetted wall ; as can be seen, the intrinsic efficiency is much improved as compared with Figs. 9 and 10. Fig. 17 is the mean



Constants relative to the graphs are :
Blade height ¼in.
Air flow 2990 cubic feet per hour at S.T.P.
Dust density 44 m.g.m. per cubic foot of air.
Mean mass efficiency 94·5 per cent.
Pressure drop across air cleaner 2·4in water.

Fig. 17—Graph of intrinsic efficiency of the air cleaner, using the wetted wall, derived as in Fig. 9

average of several test runs of the vortex air cleaner with the wetted wall and a lower r_2/r_1 ratio than used previously (i.e. decrease in height of stator blades). There is a definite improvement in efficiency of separation of the finer fractions around the 10 micron region. Ratio r_2/r_1 was reduced from 2·3 to 1·6, or blade height is reduced from $\frac{9}{16}$in to $\frac{3}{8}$in.

The dust was collected as a sludge whilst using this wetted boundary layer. Therefore added precautions had to be taken in filtering, washing with acetone, and drying of the dust collected, before the usual particle size analysis could be carried out. The water used for this wetted boundary layer was ordinary tap water which gave sufficient pressure. The acetone eliminated the likelihood of hardness deposit during the drying process.

Discussion of the Results

Consider Fig. 7. High mass efficiencies of the order of 97 per cent were obtained with length L of vortex tube 9·5in and diameter of exit cone 1·625in. These must be due to the narrow band of particle size of each grade of dust used. Theory shows that a particle has a velocity of drift dependent on centrifugal acceleration and (diameter)^2 of the particle. Therefore when dust of varying particle size from 150 microns to less than 10 microns is fed into the cleaner the larger particles travel much faster than the smaller particles, and the latter are impeded as they approach the wall of the vortex tube by the rebounding of the larger particles. This adverse effect on separating efficiency increases with increasing range of particle size.

The answers to the three objects of the investigation stated earlier can now be summarised. First, consider Fig. 10 and Fig. 16. It can be seen that the finer particles must reach the walls of the vortex tube within a specified separating length, both cases having the same condition of air flow and dust distribution. However, for Fig. 10 the wall of the vortex tube was dry and there is considerable re-entrainment of particles ranging from 130 to 10 microns. This is due to the rebounding off the walls of the larger particles, which immediately become re-entrained and afterwards scour the walls of the tube, causing considerable turbulence, which gives ideal conditions for re-entrainment of particles of all sizes. In Figs. 16 and 17 the walls of the vortex tube are wetted ; this eliminates the adverse effect of rebounding of the particles. The case now is an unimpeded drift of all particles to the wall and hence giving far better intrinsic efficiency values. Therefore it can be concluded that re-entrainment is the cause for the drop in intrinsic efficiency, and that the finer particles do reach the walls within a specified length, and if the method of the wetted wall surface is adopted a characteristic of high intrinsic efficiency is obtainable.

From application point of view the collection of the dust in the form of a sludge may or may not be desirable, but the intrinsic efficiency characteristic is good when considering the low-pressure drop of 2·6in water, for an air flow of 50 cubic feet per minute through a 2in diameter vortex tube, which can be used continuously. Also, this type of cleaner lends itself to a multiple-cell arrangement of small bulk, which can be designed to accommodate any required air flow.

A general conclusion for the investigation is that the vortex air cleaner with stator blades is primarily a separator, i.e. it shows very little classification over the range of particle size tested, as can be seen on Figs. 9 and 10. However, when the walls of the vortex tube are wetted the intrinsic efficiency is that of a classifier with the rapid drop in efficiency of separation just below the 10 microns particle size (see Fig. 17).

Acknowledgments

The author is indebted to Professor J. L. Thomson, Professor of the Mechanical Engineering Department, Royal Military College of Science, Shrivenham, Wilts, and the Director and staff of the National Gas Turbine Establishment, Ministry of Supply, for their advice during this investigation.

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Dr. William Small

By A. K. BRUCE, M.I.Mech.E., Mem.A.S.M.E.

IN the history of the Watt steam engine we find many references to William Small, who, for about nine years, was the intimate friend, physician and technical adviser of Matthew Boulton and—for some of the time—of James Watt. While a number of letters written by Small and addressed to him are preserved in Great Britain—notably the collection in the library of the Assay Office at Birmingham—it is certainly true that the influence of this remarkable man has been more widely recognised in the United States than in Great Britain. The reason lies, doubtless, in the influential part played by Small during the five and a half years through-out which he was a professor in William and Mary College at Williamsburg, Va.

Dr. William Small

Before dealing with Small's activities as a teacher and scientist, it is desirable to put on record some particulars of his early history. He was the youngest of the four children of the Reverend James Small, A.M., parish minister of Carmyllie, near Dundee, and in the record of baptisms of Carmyllie parish the entry relating to him is as follows:

"In 1734. October 20th Bapd. To Mr. James Small Minister in this Parish, by Mr. Rob Minister in Panbride, his Son William Small." The names of two witnesses are given.

Of the father, it is on record that the Reverend James Small was licensed by the Presbytery of St. Andrews on April 20, 1720, and called to Carmyllie on July 20, 1720. He died on January 3, 1771, in the fifty-first year of his ministry. In addition to his son William, the minister of Carmyllie had two other sons, Robert and James, and a daughter Anna. Robert became minister of Cross Church, Dundee, and was Moderator in 1791 of the General Assembly of The Church of Scotland. It is of interest to note that this Robert Small in addition to his gifts as a classical scholar and a preacher, was deeply versed in mathematics and in physics, notably astronomy. In 1804 he published in London an *Account of the Astronomical*

Discoveries of Kepler and in the Transactions of the Royal Society of Edinburgh there is a paper by Dr. Robert Small entitled *Demonstrations of Some of Dr. Math. Stewart's General Theorems.* The atmosphere in the manse at Carmyllie must indeed have been stimulating and we would like to know more about the mother of William and Robert Small who, before becoming the wife of the minister of Carmyllie, was a Miss Lillias Scott.

William Small received his university education at Marischal College, Aberdeen, whence he graduated M.A. in 1755. It must have been at Aberdeen that Small came under the influence of Dr. John Gregory, who, famous in his time as a physician, became professor of the practice of medicine in the University of Edinburgh. Small, it has been supposed, may have worked as an assistant to Dr. Gregory in his medical practice at Aberdeen. Thereafter he proceeded, during the early part of 1758, to Virginia, the Bishop of London (who was its titular chancellor) having appointed him to William and Mary College, Williamsburg, where he was the only member of the faculty not in Anglican orders. On October 19, 1758, Small subscribed his oath as professor of natural philosophy at William and Mary College, remaining there until some time in 1764, his name making its last appearance in the faculty journal on March 10 of that year. Sundry upheavals in the College faculty resulted in his teaching a variety of subjects including moral philosophy and Small's departure from Williamsburg is believed to have been due, primarily, to disagreement with the Board of Visitors. The available evidence suggests that this disagreement may likely have arisen from an objection to the proposal that members of the College faculty (including the president) should swear to abide by all such regulations as the Board might impose. Whatever were the precise grounds for his departure, Small returned to England during 1764—his salary was paid until September 15 of that year—bearing a commission to purchase scientific apparatus for the College, a commission which he duly carried out and for which he was remunerated. Thereafter and for reasons into which the question of health may likely have entered, Small decided not to return to Virginia.

The reputation which he left behind him at Williamsburg has been rendered specially luminous by a tribute paid to Small by Thomas Jefferson, author of the Declaration of Independence and twice president of the United States. This celebrated man had entered William and Mary College on March 25, 1760, and for upwards of three years was in close contact with Small. Long afterwards, when Jefferson came to write the autobiography now preserved among the Jefferson papers in the library of Congress, Washington, D.C., he included the following reference to his old teacher :

" It was my great good fortune, and what probably fixed the destinies of my life, that Dr. Wm. Small, of Scotland, was then Professor of Mathematics, a man profound in most of the useful branches of science, with a happy talent of communication correct and gentlemanly manners, and an enlarged and liberal mind. He, most happily for me, became soon attached to me and made me his daily companion when not engaged in the school ; and from his conversation I got my first views of the expansion of science and of the system of things in which we are placed. Fortunately, the Philosophical Chair became vacant soon after my arrival at college, and he was appointed to fill it *per interim* : and he was the first who ever gave in that college regular lectures in Ethics, Rhetoric, and Belles lettres. He returned to Europe in 1762 (*sic*), having previously filled up the measure of his goodness to me by procuring for me, from his most intimate friend, G. Wythe, a reception as a student of law, under his direction, and introduced me to the acquaintance and familiar table of Governor Fauquier, the ablest man who had ever filled that office. With him, and at his table, Dr. Small and Mr. Wythe, his *amici omnium horarum*, and myself, formed a *parti quarré* and to the habitual conversation of these occasions I owed much instruction."

One of the historians of Virginia has related how Jefferson, recalling the dinner-table conversation at the Governor's Palace at Williamsburg, remarked that at that table he had " heard more good sense, more rational and philosophical conversation than in all my life beside." Malone, writing (*Jefferson the Virginian*) of Small's influence in the college, records how it has been said that Small " more than any other teacher, was responsible for the liberality of spirit which came to characterize William and Mary, some people called it ' skepticism,' and thought it dangerous, but Jefferson and his kindred spirits regarded it as the first step towards true knowledge. Historically, William Small was a minor torch-bearer of the enlightenment, and by any reckoning he was one of those rare men who point the way, who show new paths, who open doors before the mind." It is to be remembered, moreover, that late in life, Jefferson, referring to Williamsburg, described it as " the finest school of manners and morals that ever existed in America."

We read that shortly after Small's return to Great Britain he was awarded the degree of M.D. by Marischal College, Aberdeen, and it must have been about the same time that he renewed an acquaintance with Benjamin Franklin which may have commenced—at Williamsburg—in the early part of 1763. That the two men had become friends prior to 1765 is quite certain, though there does not appear to be any reliable information as to when and where they first met. On April 2, 1756, Franklin had been awarded an honorary M.A. degree by William and Mary College but at that time Small had not yet arrived in America. Benjamin Franklin, as he has himself recorded, visited Birmingham in the summer of 1758, calling on some of his wife's relatives. In the course of this visit, Franklin (himself a master printer) made the acquaintance of John Baskerville, the famous Birmingham printer and type-founder who was his contemporary in age, having been born in 1706. When Franklin met him in 1758, Baskerville had already become a man of wealth and reputation and it may hardly be doubted that it was by his introduction that the American philospher first became acquainted with Matthew Boulton, who was his junior by twenty-two years. Discovering that they possessed a great deal in common, Franklin and Boulton continued to correspond and to exchange views regarding magnetism, electricity, clocks, steam engines and other scientific subjects. On the occasion of Franklin's next visit to England (1764–1775), he wrote a letter to Boulton, the importance of which—in the history of the steam engine—has hardly been recognised. This letter is dated May 22, 1765, and Franklin's well-known circumspection when writing letters of introduction enhances its significance :

" Mr. Baskerville informs me that you have lately had a considerable addition to your fortune, on which I sincerely congratulate you. I beg leave to introduce my friend, Doctor Small, to your acquaintance, and to recommend him to your civilities. I would not take this freedom, if I were not sure it would be agreeable to you ; and that you will thank me for adding to the number of those who from their knowledge of you must respect you, one who is both an ingenious philosopher and a most worthy honest man. If anything new in magnetism or electricity, or any other branch of natural knowledge, has occurred to your fruitful genius since I last had the pleasure of seeing you, you will by communicating it greatly oblige me."

It is a singular coincidence that this letter from Franklin to Boulton should have been written during the very month (May, 1765) in which James Watt (then in his thirtieth year), walking " on a fine Sabbath afternoon " in Glasgow Green, arrived at the idea of arranging the steam engine so that its exhaust flowed to a separate condensing vessel from which the air and water would be removed by a pump. At the time Franklin wrote his letter to Boulton, Small was in his thirty-first year and the records available show that he quickly made the acquaintance of Boulton, thereafter becoming established in Birmingham both as a physician and as technical consultant to Boulton, who was at the time particularly busy with the development of his Soho manufactory. We may be sure that among the subjects discussed on the occasion of their first meeting, or immediately afterwards, would be the difficulties experienced by Boulton in connection with the provision of power for driving the rolling, grinding, polishing and other machines in the manufactory. There were, at Soho, two water mills, and in the event of a drought it was necessary to change over to a horse mill powered by from six to ten horses. We read how Boulton, sorely hampered by this inconvenient and costly expedient, had contemplated installing a pumping engine " after Savery or Newcomen's construction, for the purpose of raising the water from the mill stream and returning it back into the reservoir, thereby maintaining a head of water sufficient to supply the water wheel and keep the mill in regular work." It must have been just about the time Dr. Small settled down at Soho that Boulton (who had not yet met James Watt) wrote to Benjamin Franklin (February 22, 1766) seeking his advice on the subject of fire engines :

" My thoughts " (writes Boulton) " about the secondary or mechanical contrivances of the engine are too numerous to trouble you with in this letter, and yet I have not been lucky enough to hit upon any that are objectionless. I therefore beg, if any thought occurs to your fertile genius which you think may be useful, or preserve me from error in the execution of this engine, you'll be so kind as to communicate it to me, and you'll very greatly oblige me."

Franklin's reply to this letter deals more with the fire-grate than any other item : " I would only repeat to you," he writes, " the hint I gave, of fixing your grate in such a manner as to burn all your smoke."

A solution in regard to the " mechanical contrivances of the engine " was, however, close at hand, since little more than a year after the date of Boulton's letter to Franklin, James Watt (introduced by Dr. Roebuck) arrived at Soho (1767) with the object of discussing his steam engine ideas with Boulton. Samuel Smiles relates how in Boulton's absence, Watt (then in his thirty-first year)

met Dr. Small (then in his thirty-third year), who showed him over the works. We need not doubt that on the occasion of his first meeting with Small, Watt explained the nature of his proposed improvements in the steam engine—they were not yet patented—and the situation in regard to negotiations with Dr. Roebuck. At all events, among the Boulton MSS. is the text of a letter to Watt dated January 7, 1768, in which Small, writing from Birmingham, explains that :

" Our friend Boulton will by this post send letters both to you and Dr. Roebuck. I know not well how to resolve without seeing you. I have not the pleasure of being enough acquainted with Dr. R. to judge whether we should all suit one another. His integrity and generosity everybody agrees are great. You certainly know the proposal he has made to Boulton, who will tell you his determination about it. Before I knew of your connexion with Dr. R. my idea was that you should settle here, and that Boulton and I should assist you as much as we could, which in any case we will most certainly do. I have no kind of doubt of your success, nor of your acquiring fortune, if you proceed upon a proper plan as to the manner of doing business ; which, if you do, you will be sole possessor of the affair even after your patent has expired. I had not thoroughly considered this part of the matter when you left me. In a partnership that I liked, I should not hesitate to employ any sum of money I can command on your scheme, and I am certain it may be managed with only a moderate capital. Whether it would be possible to manage the wheel and reciprocating engines by separate partnerships without their interfering I am not certain. If it is, Boulton and I would engage with you in either, provided you will live here."

Reading this letter, we realise the strength of the mutual trust and friendship which had grown up between Boulton and Small since the date of Benjamin Franklin's letter of introduction. Watt must have been impressed by this accord and when, on visiting Birmingham in 1769 he met Boulton for the first time, we can believe that " they at once conceived a hearty liking for each other." One upshot of this meeting was—as has been pointed out by Samuel Smiles—that Boulton, although he had begun the construction of his proposed pumping engine, decided—doubtless in agreement with Small—to proceed no further with it until he could examine the outcome of Watt and Roebuck's scheme. It has been said of Matthew Boulton that " in him nature had marvellously united boldness with circumspection." The same commentator, comparing Boulton with Roebuck, has pointed out that if Roebuck had wider and more discursive views and mental resources to carry them into execution, " Matthew Boulton's expansion of mind was more valuable, as his apparently limited purpose arose from a greater knowledge of business, and a habit of preserverence. Roebuck was impetuous in his operations, that his active mind might turn to something new ; Boulton in success contemplated only an extension of that which he had succeeded in. The first delighted in the novelty of his projects, and the other was equally pleased by an approach to greater perfection ; and he felt that those speculations which honourably advanced his own fortune, by exciting competition, added also to the public wealth." It was the peculiar good fortune of Watt that he should have been driven, by the misfortunes which overtook Roebuck, under the wing of Boulton. It was also to prove singularly fortunate for Watt that Benjamin Franklin should, at the psychological moment, have introduced William Small to Boulton. The young Scottish philosopher from Carmyllie was regarded in Birmingham—as he had been in Williamsburg—with affection and admiration. For Boulton, lately removed into his great Soho manufactory, the presence of Small as confidential friend and technical collaborator must have been precious indeed. For Watt, the presence of Small was to prove invaluable.

The subsequent history of the labours of Boulton and Watt in the development and promotion of the steam engine are too well known to need recounting here, though it must be emphasised that insufficient notice has been taken of the part played by Dr. Small. Watt did not hesitate to send Small (January 1769) a copy of the specification which he intended to annex to the application for his patent No. 913 and Small collaborated in framing the final text. It may have been by his advice that no drawings were included, since Small, in a letter to Watt, tells him that he is " certainly not obliged to teach every blockhead in the nation how to construct masterly engines." In this advice Small discloses an imperfect knowledge of patent law since not long previously it had been held by Lord Kenyon how the law demanded that " every individual to whom the King, in his wisdom, granted a monopoly, should, in writing, and otherwise if necessary, make a full disclosure of his invention, most candidly and unreservedly and in that instrument called his specification insure to the public the true knowledge and use thereof in the plainest and most descriptive manner he was able." The much-discussed sentence in Watt's specification which states how " my method of lessening the consumption of steam and consequently fuel in fire engines consists of the following *principles* " was very probably inspired by Small. Long afterwards this sentence was to move Lord Chief Justice Eyre (Boulton and Watt *v.* Bull) to remark that " it certainly was the duty of the inventor to lay down in the most instructive manner he was then able, how this machine was to be composed and made capable of the effect he had stated in his petition to the King to be thereby produced. This the law, which regulates these monopolies does require and can take nothing less and this being the price every inventor is to pay for his patent, none can have a good title deed who wilfully or ignorantly withhold a part." Dr. Small did not live to read these observations by Lord Chief Justice Eyre, since Boulton and Watt *v.* Bull (an action for infringement in which the court was equally divided and no judgment given) was not heard until 1795, by which time Small had been dead for as many as twenty years. At an early period in their friendship, Small must have taken a hand in framing the application for an extension of Watt's patent of 1769 and a coincidence to be noted is that counsel's opinion in this particular matter was given by Alexander Wedderburn—consulted early in 1775—though it does not appear that his advice was followed. Just one year earlier (on January 29, 1774) Wedderburn had attacked Benjamin Franklin before a committee of the Privy Council with a scurrility which, ignored by Franklin, was much resented by Burke, Lord Shelbourne, Priestley and some others present. Dr. Small must have heard about Wedderburn's abusive treatment of his friend Franklin, but it is unlikely that he lived to learn of the decision reached in the application for extension of Watt's patent. It is also unlikely that he knew of the plea for justice and conciliation in the conduct of American affairs which was uttered by Lord Chatham early in February 1775.

It was in a letter (March 1769) to Dr. Small that Watt, anticipating Trevithick and others in the use of high-pressure steam, explains how, in many cases, he intends " to employ the expansive force of steam to press on the piston, or whatever is used instead of one, in the same manner as the weight of the atmosphere is now employed in common fire-engines. In some cases I intend to use both the condenser and this force of steam, so that the powers of these engines will as much exceed those pressed only by the air, as the expansive power of the steam is greater than the weight of the atmosphere. In other cases, when plenty of cold water cannot be had, I intend to work the engines by the force of steam only, and to discharge it into the air by proper outlets after it has done its office." Reading the extant correspondence makes it clear how Small encouraged both Boulton and Watt in the evolution and promotion of the steam engine. We can also trace, in his letters, that charm which, at Williamsburg, had endeared him to such as Jefferson, George Wythe and Governor Fauquier : " Let nothing divert you " (writes Small to Watt in September 1770) " from the business of engineering. You are sensible that both Boulton and I engaged in the patent scheme much more from inclination to be in some degree useful to you than from any other principle ; so that if you are prosperous and happy, we do not care whether you find the scheme worth prosecuting or not." A man who could write such a letter must have appealed very strongly to Benjamin Franklin nor can we doubt that Boulton, from the outset, recognised in Small an inspiring collaborator and consultant just as Jefferson, some years earlier, had recognised in him an inspiring teacher. His complete accord with James Watt is strikingly confirmed by the correspondence which they exchanged and the more we study this correspondence the more are we impressed by the magnitude of the service rendered by Franklin to Boulton when he introduced Small.

In addition to his activities as a physician and mathematician, Small was interested in all manner of scientific and mathematical instruments, micrometers, microscopes, chronometers, watches, telescopes, lenses and barometers. He was also a student of chemistry, metallurgy and ceramics, beside which he had deeply interested himself in canals and in the propulsion of canal boats by means of a spiral oar, or screw propeller. " I am so made " (writes Small to Watt) " that I suffer no fatigue from thinking ever so long and attentively on a subject on which I can get forward." In the specification relating to the only patent for which he is known to have applied, Small describes himself as " of Birmingham, in the County of Warwick, Doctor of Physick." The patent (No. 1048) is dated July 22, 1773, and refers to " A New Method of Constructing Time-pieces of much more Simplicity than hath hitherto been in Use, which Simplicity depends upon Employing Sectors or Racks, or Levers, instead of Wheels, Scapements instead of Pinions, Roughened Circumferences instead of Teeth, Fixed Studs or Pins instead of Axes, Circles with Vernier's Divisions instead of Hands, and occasionally Centrifugal Machines instead of Ballances." The specification—there are no drawings—does little to add to the description given in the application. Reference is made to the mathematicians Paul Vernier, 1580–1637, and Pedro Nuñez (Nonius), 1492–1577, but Dr. Small has not provided such information as would be required by anyone attempting

to construct one of his time-pieces. Writing thirty-four years after the death of Dr. Small, James Keir, in a memoir on Boulton, refers to the manufacture of clocks which had been carried on at Soho manufactory. "No article," writes Keir, "was better suited to the display of invention, and accordingly clocks were made of various constructions; of these, one contained but a single wheel, and a timepiece of this kind was made which proved the truth of the principles of the invention. This one-wheeled clock was invented by Mr. B.'s intimate Friend, Dr. Small, who added to his many excellent endowments inventive genius united with the more rare advantage of calculating the precise results of mechanical problems by his superior mathematical skill. . . ."

Portable clocks and watches were little known and used until the second half of the seventeenth century. Huygen's first pendulum clock had appeared in 1657. Hooke—who has a claim to the invention of the spiral spring balance for regulating watches—died in 1703, and Tompion, the father of English watch and clock-making, who collaborated closely with Hooke, was alive until 1713. Samuel Pepys tells us (*Diary* entry for December 22, 1665) how he proceeded to the house of Lord Brouncker (then president of the Royal Society) "and there spent the evening by my desire in seeing his Lordship open to pieces and make up again his watch, thereby being taught what I never knew before; and it is a thing very well worth my having seen, and am mightily pleased and satisfied with it." It is on record that Benjamin Franklin was among those scientists who took a particular interest in clocks and we read how he devised, about 1744, a time-piece which, having only three wheels and two pinions in the movement, told the hours, minutes and seconds. Richard Lovell Edgeworth—a close friend of Small—worked on clock mechanisms and doubtless discussed the subject with Small and Boulton. He did not apply for any patents in connection with clocks, though a patent (No. 953) granted to him on February 5, 1770, relates to "Portable railway or artificial road."

Mention has been made of the part played by Dr. Small in that *parti quarré* which proved such an inspiration to Thomas Jefferson when he was a student at Williamsburg. Later, Small was to become, in Birmingham, the leading spirit in the establishment of that celebrated Lunar Society which, during the second half of the eighteenth century, drew together the most eminent men in Birmingham and the district round about. Samuel Smiles, after remarking that the formation of the society was probably suggested by Dr. Small, goes on to state that "The object of the proposed society was to be at the same time friendly and scientific. The members were to exchange views with each other on topics relating to literature, art and science; each contributing his quota of entertainment and instruction. The meetings were appointed to be held monthly at the full of the moon, to enable distant members to drive home by moonlight." In addition to Matthew Boulton and William Small, the members included Joseph Priestley, James Watt, Erasmus Darwin, James Keir, John Baskerville the printer, Thomas Day, Samuel Galton, R. Lovell Edgeworth, Josiah Wedgwood, and other famous men. In this illustrious circle the outstanding poet was Erasmus Darwin, and a hint of the extent to which the steam engine was an object of discussion is conveyed by his lines:

> Soon shall thy arm, unconquered steam! afar
> Drag the slow barge, or drive the rapid car;
> Or, on wide-waving wings, expanded bear
> The flying chariot through the fields of air.

The death of Dr. Small on February 25, 1775 (he was then in his forty-first year) came as a great shock to Matthew Boulton and to James Watt.

Dr. Small had never been physically robust and during the last year of his life appears to have rapidly declined. It may be that the death of his mother—which occurred just three weeks before his own—hastened the end. During the few years which had elapsed since Benjamin Franklin brought them together, Small had become not only the beloved personal friend of Boulton and of Watt, but their close collaborator in the development of the steam engine. Samuel Smiles relates how it was intended, on the granting of the extension of the patent, to include Small in the steam engine partnership. "He had" (writes Smiles) "been consulted in all stages of the proceedings, and one of the last things he did was to draw up Watt's petition for the bill," that is, the application for the extension of patent No. 913. The depth of Boulton's distress at the death of Small is reflected in the moving letter which he sent to Watt, who was in London at the time:

"The last scene has just closed; the curtain has fallen and I have this evening bid adieu to our once good and virtuous friend for ever and ever. If there were not a few other objects yet remaining for me to settle my affections upon, I should wish also to take up my abode in the mansions of the dead."

It is most singular that so many of the men whose names are prominently associated with the creation and development of the steam engine should be buried in unmarked graves. We seek in vain for the resting places of Papin, Savery, Newcomen, Rumsey, Symington and Trevithick, and while we know that Dr. Small was buried on March 15, 1775, in St. Philip's churchyard, Birmingham, there is no memorial or other record enabling us to identify the spot. If, however, there is no inscription to his memory, luminous indeed are the memorials which we find in the record of his activities and in the tributes paid to him by his friends. We can think of no other engineer, who, living in the eighteenth century, has been praised in such terms by so illustrious a quartette as Benjamin Franklin, Thomas Jefferson, Matthew Boulton and James Watt. Indeed, in the accounts of his versatility as a mathematician and scientist, Dr. Small may remind us of another celebrated son of the manse—Robert Hooke—who was born a century earlier. The association between Boulton and Small is certainly reminiscent of the association between Sir Christopher Wren and Hooke, since in each case it was a collaboration in scientific activity as well as an affectionate and indissoluble mutual friendship. Small was as much beloved by his friends in Birmingham as he had been by his friends in Williamsburg and R. Lovell Edgeworth, writing in his *Memoirs*, has this to say of him:

"By means of Mr. Keir I became acquainted with Dr. Small of Birmingham, a man esteemed by all who knew him, and by all who were admitted to his friendship beloved with no common enthusiasm. Dr. Small formed a link which combined Mr. Boulton, Mr. Watt, Dr. Darwin, Mr. Wedgwood, Mr. Day and myself together—men of very different characters, but all devoted to literature and science."

Malone, discussing (*Jefferson the Virginian*) the considerations which led Jefferson to study law under the guidance of Wythe, remarks how "His choice of Wythe as a guide instead of one of the Randolphs or somebody else, and Wythe's agreement to receive him, were probably owing to their mutual friend, William Small. He was eternally grateful for these good offices and always convinced of the wisdom of his decision, not merely because his mentor was the most learned and possibly the most effective of the local group, but also because of the greater range and liberality of his mind."

In his book entitled *The Head and Heart of Thomas Jefferson* John Dos Passos relates how "Small discovered at Williamsburg what so many innovators have discovered before and since, that no man can meddle with the established conformities of an institution of learning and come out with a whole skin. Years later he wrote dryly to his friend Watt that he was 'no stranger to the inconveniences of an academical life.' Fortunately for him . . . he had his medical degree and, with the help of another free-thinker and philosopher, the omnipresent Dr. Franklin, had established himself in a career among warm friends in Birmingham which was to lend brilliance to the last years of his short life." The most exquisite tribute to Small is found, however, in a letter written by Thomas Jefferson to his grandson. This letter is the more touching by reason of the light which it throws not only on the individuals mentioned, but on him who mentions them:

"Under temptations and difficulties" (writes Jefferson) "I would ask myself what would Dr. Small, Mr. Wythe, Peyton Randolph do in this situation? . . . I am certain that this mode of deciding on my conduct tended more to its correctness than any reasoning powers I possessed."

In a brief sketch written by Herbert L. Ganter, Archivist at the College of William and Mary and published in the *William and Mary Quarterly*, 1947 (Vol. 4, Third Series, pages 505–511), it is related how a search over a period of some ten years for letters exchanged between Jefferson and Small "has been almost fruitless. One letter only has come to light, written by Jefferson to Small and dated May 7, 1775. A great part of this letter is concerned with military and political matters, only the opening and concluding portions being given hereunder:

"Thomas Jefferson to William Small,

Virginia, May 7, 1775.

"Dear Sir,—I had the pleasure by a gentleman who saw you at Birmingham to hear of your welfare. By capt. Aselby of the *True Patriot* belonging to Messrs. Farrell & Jones of Bristol I send you three dozen bottles of Madeira, it being the half of a present which I had laid by for you. The captain was afraid to take more on board lest it should draw upon him the officers of the customs. The remaining three dozen therefore I propose to send by capt. Drew belonging to the same mercantile house, who is daily expected just arrived here. That which goes by Aselby will be delivered by him to your order; the residue by Drew, or by Farrell & Jones, I know not which as yet. I hope you will find it fine as it came to me genuine from the island and has been kept in my own cellar eight years."

"I sat down only to ask your acceptance of the wine & express my constant wishes for your happiness. This however seems to be secured by your philosophy & peaceful vocation. I shall still hope that amidst public dissention private friendship may be preserved inviolate, and among the warmest you can ever possess is that of

"Your obliged humble servt.

Th. Jefferson".

This beautiful letter never reached Dr. Small, who had died just ten weeks before it was written. It may be regarded, however, not only as a memorial to William Small but

as a memorial also to the author of the Declaration of Independence.

The portrait of Dr. Small is reproduced—by kind permission of the Assay Master, Mr. A. H. Westwood—from a pencil drawing which, the work of an unknown artist, is preserved at the Assay Office, Birmingham. It is believed to be the only existing likeness of William Small. Grateful acknowledgment is also made in respect of information kindly provided by the Reverend A. Ian Dunlop, of St. Stephens, Edinburgh, by Mr. Herbert L. Ganter, Archivist at the College of William and Mary, Williamsburg, and by Mr. Clarence Blackburn, of Knoxville, Tennessee.

American 4-4-0 Locomotives

(Contributed)

WITH reference to the excellent engraving of 1857 reproduced in the issue of January 27, 1956 illustrating the American 4–4–0 type locomotive of that period, it is interesting to recall that the last and final locomotive of 4ft 8½in gauge to be built to this wheel arrangement in the United States was outshopped in 1926. Two of these engines were built for the Chicago and Illinois Midland Railroad for passenger service. They were the last standard gauge 4–4–0s to be built for an American railroad and they are still in existence at the present time, although they have been withdrawn from passenger service. No. 502, which for several years ran daily one of the C. and I.M.'s principal passenger trains from Springfield, Illinois, to Pekin, a distance of 76 miles, was retired from this service early in 1953, but the engine was, in 1955, engaged in light freight and switching service. Fig. 1 shows this engine at Springfield, Illinois, in 1950. In August, 1945, however, the Baldwin Locomotive Works of Philadelphia, Pa, manufactured two 4–4–0 locomotives for the narrow (3ft) gauge lines of the United Railways of Yucatan, South America, and Fig. 2 shows one of these engines in the Philadelphia Works in 1945, where the Baldwin Company's photographers are seen taking an official photograph of the locomotive. These two Mexican outside cylinder engines are still in service at the present time and no further 4–4–0 types were built in America after this. A few remarks concerning the earlier types of American 4–4–0 locomotives may not be without interest. The arrangement of four leading wheels and a similar number of driving wheels was suggested in America as early as 1834. In that year the Pennsylvania State Railroad (later the Pennsylvania R.R.) ordered a small number of powerful locomotives for merchandise service from the Sellers Bros. who were four young owners of some machine shops. They suggested this wheel arrangement but officialdom frowned on the idea, and it was two years later before the first American 4–4–0 type, or "Eight Wheeler" as it became known, made its appearance. In 1836 Henry R. Campbell, of the Philadelphia and Germantown Railroad (later Reading R.R.), prepared designs for an engine of this type. It was outshopped by James Brooks, but did not prove entirely successful. It rode hard on the track due to the fact that the driving wheels were not equalised. It may be said, however, that this locomotive was the forerunner of the many and varied designs of 4–4–0 locomotives that were to appear during the next sixty years. The 4–4–0 type in that period became the universal dual purpose (passenger and freight) type on American railroads where it became known as the "American" type or "Eight Wheeler." The 1870–80s perhaps marked somewhat the zenith of its development from the earlier types. In that period some outstanding specimens appeared. Perhaps among the more noteworthy being the celebrated Class "A" engines designed by Godfrey W. Rhodes for the Chicago, Burlington and Quincy R.R. These engines were made with two cylinder sizes—17in and 18in diameter, and had driving wheels of 69in and 65in diameter for passenger and freight duties respectively. They were developed from the earlier C.B. and Q. engines of 1861 which were used extensively on freight service. Fig. 3 shows one of these early engines on freight work at Batavia, Illinois, in the year 1864. They had 65in diameter wheels and weighed just over 37 tons in road order (without tender) The Pennsylvannia R.R. engine illustrated in Fig. 4 is a typical example of the advanced anthracite burning period of 1889 onwards, when such locomotives began to appear with capstack chimneys. The engine is shown in passenger service at the Union Station, Indianapolis, Ind., in the year 1894.

It may be of further interest to add that at present the oldest known working locomotive in service in the U.S. is a 4–4–0 engine built in 1867 and which is, or was, in use on the 14-mile Stockton Terminal and Eastern railway in California. This engine was originally built for the Central Pacific Railroad which later became merged into the present Southern Pacific Lines, who eventually sold the engine to the S. T. and E. short line.

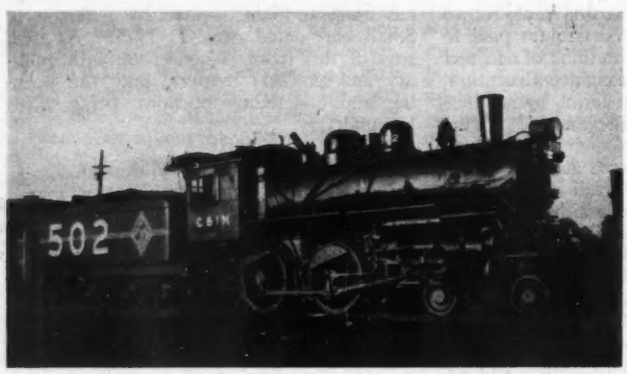


Fig. 1—One of the last 4–4–0 engines built for American railway—*circa* 1926

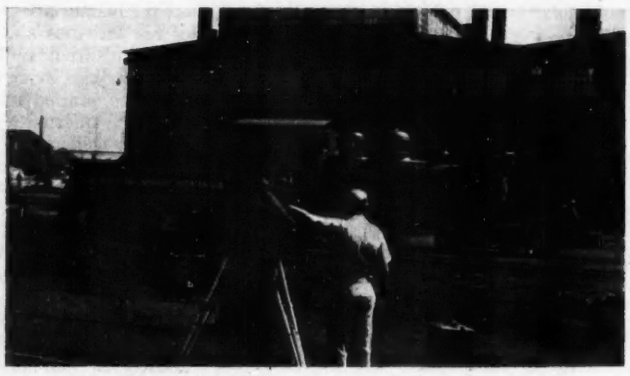


Fig. 2—Narrow gauge 4–4–0 engine for Yucatan, built in U.S. in 1945

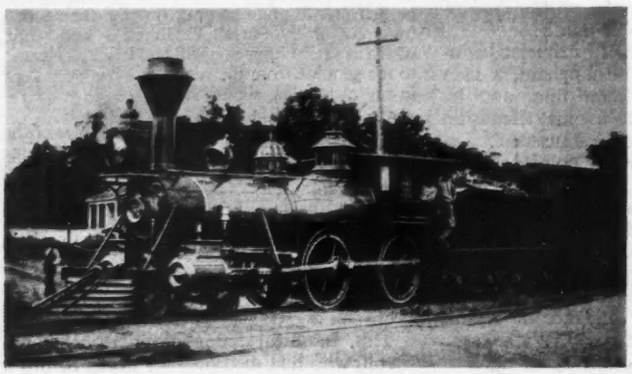


Fig. 3—Early American 4–4–0 engine—*circa* 1864

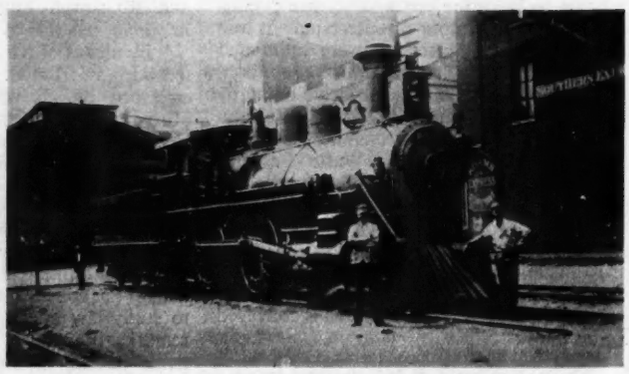


Fig. 4—Anthracite-burning 4–4–0 engine—*circa* 1890

Scottish Water Power Developments

THE North of Scotland Hydro-Electric Board has just published its annual report for 1956, and also details of its constructional scheme No. 30, known as the Strathfarrar and Kilmorack scheme.

Financially, 1956 was again a bleak year for the Board. The report recalls that in June the Board gave a pledge to the Government not to raise its tariffs during 1956, to help in stabilising the cost of living. The pledge was made at a time when the Highlands had just experienced a drought which, the Board estimated, had cost it £1,100,000 and left, at the end of 1955, a loss of £446,884. During 1956, costs continued to rise and in increased interest rates alone the Board points out, it paid £270,000 more than it would have paid if interest had been at the same rate as in 1955. There was thus a loss on the year's working of £165,693, which raised the debit balance to £612,577 at the end of the year. The Board considers that even with the exercise of the utmost economy, the continuation of these conditions will make it imperative to reconsider tariffs. The effect of the Government's restrictions on capital expenditure is reflected in a drop of some £2,600,000 in expenditure on capital account. Half of this reduction was on distribution, resulting in a much reduced rate of connection in rural areas, and, in total, a reduction, compared with last year, of 2633 in the number of new consumers. The actual number of new consumers was 13,382, bringing the total number of consumers in the North of Scotland up to 351,524, of whom 163,000 have been connected to the mains since 1948.

The Board again draws attention to the effect of rising prices on the cost of connecting new consumers in its widely scattered area. It takes the view that if it is State policy to put electrical power at the disposal of agriculture, then it is for consideration how far the cost of this service in such a scattered area (74 per cent of the land area of Scotland) should be met from the Board's resources, or, as in many other agricultural countries, from national funds.

Electricity Generation and New Plant.—During 1956, the Board increased the capacity of its water power stations to 660MW, and generated 1744 million units of electricity from its hydro, steam and diesel stations ; 67 per cent of this total was used to supply its own consumers and the balance was sold to the South of Scotland Electricity Board. In contrast to 1955, delivery of energy to the South of Scotland Electricity Board exceeded by a substantial amount the quantity specified in the agreement between the Boards. The amount in excess of the specified export of 296 million units was 66,000,000 units ; 57,000,000 units were imported by the Board.

During the year the Board brought into commercial operation for the first time a further 101·5MW of hydro-electric plant. The stage reached in the development of water power thus became :

Hydro-electric schemes	Capacity (MW)	Average output (million units per annum)
Already in operation	660	1666·25
Under construction	210	764·00
Promoted, but work not started	38	121·4
In course of promotion and survey	704	1366·0
	1612	3917·65

Good progress was made with schemes under construction and another 85MW of new hydro-electric plant should be ready to commission before the end of 1957. In addition, work is well advanced on a new 30MW steam installation at Dundee.

Extensions to the 132kV Highland grid put into commission during the year included lines between Clunie power station in the Tummel Valley and Charleston near Dundee, and from Fort Augustus to Fort William. Demand for electricity in the Board's area increased by 10 per cent, compared with an increase of 12½ per cent in 1955. Water storage reserve was built up by 170 million units during the year. The maximum demand of the consumers in all areas reached a peak of 377MW in February.

The total capital expenditure during the year amounted to £19,473,000 and the aggregate capital expenditure to the end of the year was £160,024,000, subdivided as follows :—

	£
Hydro-electric schemes	108,602,000
Steam and diesel power stations	4,840,000
Transmission lines	12,396,000
Distribution	32,734,000
Sundry	1,452,000
	£160,024,000

Promotion and Survey of New Schemes.—Apart from the scheme in Glen Strathfarrar, described below, the scheme to develop the resources of the River Awe and its tributaries, the Nant and the Cruachan Burn, was also brought to a more advanced state of preparation. It possesses features which make it attractive for the development of pumped storage. Investigation of pumped storage schemes continues because of the flexibility and operating advantages they offer in association with large nuclear and high-efficiency conventional steam stations. In addition to more detailed examination of the development of pumped storage at Loch Awe, site investigations have been carried out at Burn of Mar (Balmaha) and at Loch Sloy, both of which would utilise Loch Lomond. To solve some of the problems which arise there model investigations have been put in hand.

Investigations into the development of the water power resources of the River Tay at Kenmore and Grandtully were directed mainly to the fishery problems involved. Further surveys were carried out in the area of the Monadhliath Mountains, the Upper River Findhorn, in Glen Nevis and in Skye at the Rivert Snizort. Exploratory boring work was carried out at the outlet of Loch Laidon to find the best site for a dam.

A number of likely sites for nuclear generation are being investigated and a contract has been placed for the drilling of trial bores in North-East Aberdeenshire.

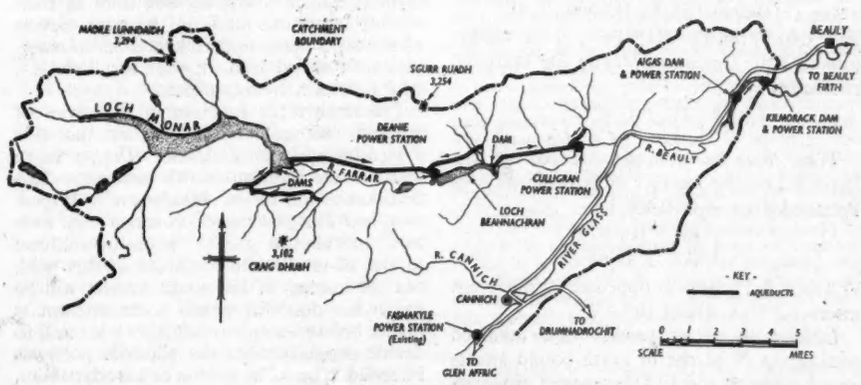
Works Under Construction.—Hydro-electric schemes under construction have a total capacity of 210MW. The total length of rock tunnel driven during 1956 was 19·25 miles, or 8500ft a month. The total now driven is 129 miles. At the end of the year the dams at Glascarnoch, Vaich, Fannich, Lednock and Shin were all approaching completion, while at Lubreoch approximately 72 per cent of the total concrete had been placed. Fly ash continued to be used in the concrete at Lubreoch and Lednock dams. At Cluanie and Loyne dams, where wet-ground blast-furnace slag was used, the total saving of cement is stated to be 36,220 tons. Further savings amounting to 10,190 tons were made by using blast-furnace slag in the linings of the tunnels at Upper Glenmoriston and St. Fillans.

Gas Turbines.—As a result of troubles experienced last year, the compressor blading of the experimental gas turbine at Dundee has been redesigned and the manufacture of the new blading is in hand. The plant should be available for further test runs in 1957 it is stated.

The power station building at Olgrinbeg in Caithness has been completed and erection of peat handling and pulverising plant has commenced. The manufacture of the 2000kW gas turbine generating plant is nearing completion and is due to undergo test in 1957.

Strathfarrar and Kilmorack Scheme.—The accompanying diagram shows the Board's proposals for the development of the Farrar and Beauly rivers in Inverness-shire. These proposals complete the main works needed to utilise the Beauly catchment, a first stage of which was achieved when the Mullardoch-Fasnakyle-Affric scheme was completed in 1952.* The new works will make use of a catchment 350 square miles in extent, of which 124 square miles is controlled by the Affric scheme. The total installed capacity will be 102MW, in four power stations, and the estimated annual output 268 million kWh. The estimated cost of the scheme is £14,250,000. By comparison, the installed capacity of the Affric scheme (at Fasnakyle power station) is 66MW, and the annual output 236 million kWh.

In the upper section of the new scheme, the available head from the river Farrar will be developed in two power stations. The upper section will include a dam 110ft high across the river about 1 mile downstream of Loch Monar. There will also be a subsidiary dam 50ft high in a low saddle to the west of the main dam. The level of the loch will be raised by 75ft and its area enlarged considerably. The reservoir so formed will provide the main storage for the Farrar power stations. The catchment area of Loch Monar will be augmented by diverting back into the reservoir water from the Uisge Misgeach and other tributaries which join the River Farrar below the dam site. From Loch Monar the water will be led by a tunnel 5¾ miles in length to a power station near Deanie at the west end of Loch Beannachran. This tunnel will collect water from the side streams which it crosses *en route* to the power station. The installed generating plant capacity will be about 38MW.



The Farrar and Kilmorack project

To supply the lower power station, Loch Beannachran will be raised in level by about 8ft. This will be done by a small dam ¾ mile downstream from its outlet, and, from the upstream side of the dam, a tunnel 3½ miles in length will lead water to the Culligran power station on the left bank of the River Farrar downstream of the Culligran Falls. The tunnel will also intercept water from side streams on the left bank of the River Farrar. Culligran power station will have generating plant of capacity of about 24MW.

It is also proposed to pass the waters of the River Beauly through two power stations. This will involve the construction of two dams, each about 50ft in height and each with a power station of about 20MW capacity built into the dam. The river flow here will be regulated by both the Farrar and Affric reservoirs. The upper dam will be about ¾ mile north of Crask of Aigas and the water from its power station will discharge straight into the headpond formed by the dam lower down the river at Kilmorack. In the interests of fisheries, Borland fish passes (which operate on much the same principle as a canal lock) will be installed in the two dams at Kilmorack and also at Beannachran. Compensation water will be released from Loch Monar and from Loch Beannachran. The output will be fed into the Highland grid at Beauly.

* See THE ENGINEER, April 11, 18 and 25, 1952.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents.)

AN INDUSTRIAL APPLICATION OF COMPUTERS

SIR,—It is to be hoped, indeed, that Mr. Berners-Lee, following his article on page 169 of your February 1 issue, has not tried to programme "Pegasus" to determine his best way to the office in a morning. Even with his simplified array of 60×60 streets he would have to multiply the time he allowed for the computation by a factor greater than 10^{16} to obtain the correct one! Although it is certainly true that at any of the crossroads within his array there is a choice of paths, there are 59^2 such junctions, not just 60, and, in addition, 59 points along each of the northern and eastern boundaries at which no such choice exists. The simplest way of considering such a problem appears to be this. Assume that there are $f(m, n)$ ways of travelling northwards and eastwards from A to Z across an array of $m\times n$ streets. If B and C are the junctions immediately to the north and east of A, the corresponding numbers of ways from B to Z and from C to Z are $f(m, n-1)$, $f(m-1, n)$. Since B and C can each only be reached in one way from A,

$$f(m, n)=f(m, n-1)+f(m-1, n)$$

and since $f(m, 1)=f(1, n)=1$, it is readily proved that $f(m, n)$ is exactly the binomial coefficient

$$\binom{m+n-2}{m-1}\equiv\binom{m+n-2}{n-1}.$$

Thus, for the example quoted by Mr. Berners-Lee, the number of possible ways to Portland Place is $f(60,60)$, i.e.

$$\binom{118}{59}=\frac{118!}{(59!)^2},$$

or about $2\cdot5\times10^{34}$, as opposed to the given number 2^{60}, i.e. about 10^{18}.

Incidentally, road repairs that involved cutting the i^{th} of the m north-bound streets between the j^{th} and $j+1^{th}$ east-west crossings would reduce the number of ways by

$$f(i, j)\times f(m-i, n-j-1).$$

G. H. ROOM

Admiralty Experiment Works,
Haslar, Gosport,
Hants,
February, 18, 1957.

GEORGE JACKSON CHURCHWARD

SIR,—I do appreciate the compliments expressed and implied in Mr. Kenneth H. Leech's letter on this subject although I must add that the design mentioned in his last paragraph incorporated only one feature (top-feed) that can be particularly associated with Churchward. Any engineer who studies the subject is bound to admire Churchward's work as a locomotive engineer. It is appropriate that such admiration be expressed in THE ENGINEER (at the centenary of his birth or at any other time) but not in tones of uncomprehending emotion. That can only harm his reputation.

W. A. TUPLIN

Sheffield, 10,
February 23, 1957.

Literature

Principles of Guided Missile Design: Aerodynamics, Propulsion, Structures. By E. A. BONNEY, M. J. ZUCROW and C. W. BESSERER. Macmillan and Co., St. Martin's Street, London, W.C.2. Price 75s.

BY the end of 1956 the United States of America had spent over £1900 million on the investigation, design and production of guided missiles and over thirty families of weapons had reached the hardware stage. This mammoth sum, and the diversity of the products, indicates the magnitude of the corps of technicians, designers and engineers devoted to the development of this "new" branch of aeronautics. In this country, where the effort is naturally much smaller, over 150 firms are engaged on some phase of missile activity (on missile power plants, guidance and test equipment, materials, &c.). It is not perhaps unexpected that the state of the "art" in the United States is further advanced than in Britain, and although a three-year phase lag has been mooted in some circles, it is doubtful if this figure is realistic and anything up to ten years is more likely. It follows that although we are behind and need an intensive effort to build up our design facilities, the Americans have the bigger problem of not only building up further, but of educating and training their already enormous staffs in the finer aspects of the tasks being undertaken so as to maintain their world lead in what for them is a vital field of national defence.

Presumably the function of the series of volumes being published under the title *Principles of Guided Missile Design* is to assist in the solution of this problem. This addition to the series, *Aerodynamics, Propulsion, and Design Practice*, covers a very wide area and should provide a useful addition to the all-too-limited literature in this field, but the success of the whole project will be somewhat doubtful unless some attempt is made, before issuing any further volumes, to decide precisely what the editorial policy is intended to be. The section on aerodynamics, by E. A. Bonney, of the John Hopkins University, very much resembles an incomplete and ill-assorted data book or aerodynamic dictionary. It contains very useful information on a large variety of aspects—many of which have no place in this volume. Thus, the section on wind tunnels is useful and the specialised techniques are described quite well, but it is difficult to understand why so much space is devoted to these and to equally out of place—but excellent—explanations of how to write wind tunnel and aerodynamic loading reports. This space could better have been used to extend and clarify the explanation of shock wave formation, part of which appears technically indefensible. It is difficult to be critical of omissions when subsequent volumes may remedy them; but one glaring deficiency appears in the chapter on flight testing. There is only a very half-hearted attempt to explain how missiles are tracked, how the information is fed back and the data reduced. The word Doppler does not even appear in the index. The general impression left by the aerodynamics section is that it is sadly in need of revision to give more fundamentals and less unnecessary appendages.

In great contrast the section on propulsion by Professor Zucrow is excellent. The chapters on diffusers and turbo-jets are well presented and both the theoretical and computational aspects covered in an authoritative manner. There is little doubt that this is the backbone of the volume, and although marred by a notation somewhat complicated by British standards, it makes a difficult subject seem within the grasp of most technicians. Two minor criticisms might be levelled. It is difficult to understand why readers, familiar with some of the complicated mathematics needed for this subject, should require a definition of momentum; to follow this a few lines later by a mathematical statement of the definition which involves differentiation and particle summation seems at least a little out of focus. The chapter on the kinematics of rocket-driven missiles also seems a little out of place. But these are little things and are very soon forgotten in the face of the otherwise unqualified success of the section.

The final section by C. W. Besserer on structures and design practice combines some of the failings of the aerodynamics section with many of the virtues of the propulsion section. It contains some excellent chapters, such as those dealing with materials and weight control. The general impression is that the aim is to give understanding rather than potted data, as in the aerodynamics section. This impression, supplemented as it is by the valuable detailed information given, is, however, spoiled by the paucity of data on structures. The chapter on packaging (or chassis design) is exceptionally valuable. Missing, however, is any detail on the flutter problem ("flutter" is not to be found in the index!), and equally redundant is the wealth of information given in the long table dealing with the accuracy of common machine tool operations. All in all, the section, excellent as it is in some respects, displays that lack of overall editorial control needed in an undertaking of this magnitude to ensure that all aspects are suitably and evenly embraced.

Summing up, this volume makes a useful contribution to missile literature and will be found of value to those concerned with the problem of missile design. However, as a suitable book for use in the training of technicians and as a handbook it fails in its task.

Théorie et Technique des Asservissements. By J. C. GILLE, M. PELEGRIN and P. DECAULNE. Dunod, 92, Bonaparte, Paris (6e). Price Fr. 9·300.

THE aim of this book, according to the authors in the foreword, is threefold—first, to provide a progressive course on servo theory and techniques for students and teachers; secondly, to supply a compendium of the published literature on servo systems for use as a reference by engineers, and, finally, to give the general scientific and technical public an appreciation of the concepts and problems involved in the subject. The authors have obviously borne in mind the needs of students and teachers by their adherence to a strictly logical order of presentation and illustration of each step by examples and diagrams. All important points, such as definitions and theorems, are set out with commendable clarity. To cater for the practical engineer, mathematics have been reduced to the indispensable minimum by merely stating most theorems in the text and including their proofs in appendices. The conditions of validity of all results are,

however, clearly stated in the main text. Physical interpretation never gets bogged down in a morass of theoretical abstraction and the reader is never left in doubt as to the orders of magnitude involved. The numerous graphical methods used in practice are explained and quite a few auxiliary curves are included. This clarity and lack of complexity in the presentation of the subject matter make it reasonably easy for the general reader to acquire a sound basic appreciation of servo theory and techniques.

The book is divided into an introduction and five main parts, further subdivided into chapters. The main principles of servo systems and their classification according to input and output characteristics are outlined in the introduction, together with a qualitative description of the purpose and general operation of the elements of the typical servo loop.

Part I is devoted to the general dynamics of linear systems. First, the formulation of the equations is treated, with instructive examples, followed by an introduction to the analogue. In the succeeding chapters, transients and their relation to stability are discussed and the Laplace Transform is explained, the proofs of the theorems involved being given in the appendix. Then comes a discussion of first order systems, the Nyquist diagram, gain and phase plots and the concept of the transfer function. In the next chapter the frequency and indicial responses of second order systems are dealt with in great detail and the reader is introduced to the inverse transfer function diagram. The remainder of the first part of the book consists of chapters on the properties of linear systems in general, including transfer functions, their calculation and experimental determination ; the application of the preceding theory to the study of vibrations ; stability and criteria of stability ; an examination of linear equations with time variable coefficients, and, finally, a chapter on random inputs with the introduction of the frequency spectrum and Weiner's prediction theory.

The second part deals with the now classical theory of linear servo systems. In the first chapter, the transfer function concept is extended and applied to open and closed loop systems. The next chapter studies the steady states of servo systems and subsequently the stability theory and criteria already discussed in Part I are applied to servos and methods of stabilisation are considered. Part II ends with a study of the application of complex variable theory to linear servo systems and an extension of the theory to systems with several variables.

Part III extends the scope of the book to include the definition and classification of non-linear systems and the enumeration of the non-linearities encountered in servo systems. Relay servos are next given a fairly full treatment, followed by a chapter on the application of Poincaré's Theorems and a few notes on the other available methods of approach.

Error-detecting devices are the subject of the first chapter of Part IV, which deals with the elements of servo systems. A comprehensive treatment of the problem of noise is followed by chapters on the properties of actuators in general and electric and hydraulic motors in greater detail. The section ends with a detailed treatment of amplifiers and preamplifiers in which electronic, relay and rotary amplifiers are all considered and the advantages of each are discussed.

The preliminary design of a servo system is considered in the final section of the book, and, after some general comments, two examples are taken and discussed in some detail. Both of these, the first a position servo and the second an "autopilot" system for a guided missile, are instructively treated.

Most of the existing works on servo systems have emphasised some particular aspects of the subject or omitted some topics entirely. The value of this book is that it gives a comprehensive treatment of the field and therefore fulfils the purposes of providing a broad basic knowledge for the student and a reliable reference for the engineer.

Metallurgical Analysis by Means of the Spekker Photoelectric Absorptiometer. By F. W. HAYWOOD and A. A. R. WOOD. Hilger and Watts, Ltd., 98, St. Pancras Way, London, N.W.1. Price 40s.

COLORIMETRIC analysis is one of the oldest procedures in analytical chemistry. Early work with this method was largely empirical. Quantitatively its value was mainly in the determination of "traces," but during the past twenty-five years or so instruments have been introduced making colorimetry an important method of accurate analysis, which may be applied to quite large percentages of components in a solution. This is mainly due to the replacement of visual colorimetry by photoelectric absorptiometry or the measurement of the optical density of the solution under test, i.e. the percentage transmission of light of a selected spectral region through the test solution. There is no further need for the preparation of standards when once the quantitative relationship between concentration and optical density has been established.

Of these instruments, the Spekker photoelectric absorptiometer is by far the most widely used in this country at the present time, both for routine and research purposes. This book, a greatly enlarged version of the first edition which appeared thirteen years ago, should therefore find a place in all laboratories dealing with metallurgical analysis. The first part of the book deals with absorptiometric principles, and contains a description of the Spekker in its earlier and latest form, with full instructions for its operation. Faults which may arise in the instrument are described in an appendix, with an indication of their cause and method of correction. The second part contains details of recommended procedure in the analysis of steels, aluminium, copper, lead and zinc alloys. There is also an extensive bibliography. Laboratories which have specialised in one or other of these types of materials may have developed minor differences in technique, but the methods described are those which have given reliable service. Beginners will find the book a valuable guide, and it will go far to remove difficulties which may still be encountered by experienced users of the instrument, who will also find it an indispensable book of reference.

Books Received

Capstan and Turret Lathe Handbook. By F. J. Camm. George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 25s.

Boiler House Practice. Second edition. By J. N. Williams. George Allen and Unwin, Ltd., Ruskin House, Museum Street, London, W.C.1. Price 60s.

Solar Radiation in Air Conditioning. By Ivor S. Groundwater. Crosby, Lockwood and Son, Ltd., 26, Old Brompton Road, London, S.W.7. Price 25s.

Mechanical Design for Electronics Production. By John M. Carroll. McGraw-Hill Book Company, McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 49s.

Hand List of Short Titles of Current Periodicals in the Science Library. Compiled by the Ministry of Education Science Museum. Eighth edition. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 12s. 6d.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

IRON CASTINGS WITH SPHEROIDAL OR NODULAR GRAPHITE

No. 2789 : 1956. Price 3s. 6d.—This is a new British Standard to cover a type of iron which has recently been developed. This iron has properties fundamentally different from those of normal grey iron with flake graphite. In particular, it possesses greater tensile strength and may acquire a considerable degree of ductility together with a resistance to impact many times greater than that of grey graphite iron. The standard includes requirements not only for tensile strength, but also for elongation, hardness, permanent set stress and, in certain cases, resistance to impact. It covers the bulk of the commercial applications and caters for three types of iron—those having a mainly pearlitic matrix characterised by high tensile strength, but in which ductility and resistance to impact are of less importance ; those having a mainly ferritic matrix of moderately high tensile strength in which high ductility and toughness are of great importance, and those having a ferritic matrix in which resistance to impact is of paramount importance.

Materials falling between the mainly pearlitic and mainly ferritic grades may be obtained by adjustment of the composition or by appropriate heat-treatment. Further, the iron may also be alloyed to produce acicular, martensitic and austenitic irons. However, the major interest has been in the classes quoted above, and the British Standard is at present confined to those classes for which there is a firm basis of experimental and production data.

ORGANIC BAKING IMPREGNATING VARNISHES FOR ELECTRICAL PURPOSES

No. 2778 : 1956. Price 3s.—This standard supersedes B.S. 119 : 1930, "Clear Baking Oil Insulating Varnish for Electrical Purposes," and B.S. 514 : 1933 "Baking Insulation Varnish (Bitumen Type) for Electrical Purposes." When B.S. 119 and B.S. 514 were produced the so-called synthetic varnishes had not come into general use and the opportunity has now been taken to include these varnishes in a general specification for impregnating varnishes. A test for polymerisation has been incorporated in the new standard. A considerable reduction has been made in the maximum permissible drying time to bring this into accord with current practice and the drying must be carried out at any one of three stated temperatures. The determination of resistance to moisture now calls for total immersion instead of subjection to 95 per cent relative humidity, and the test for ageing has been amended and is now called a test for the effect of heat ageing on flexibility. Although the specification does not require that the varnishes should be suitable for use in insulating oil, many of them will in fact be suitable. Some varnishes complying with this specification will be affected by contact with cutting oil. No clause has been included to cover this property and where contact with such oil is likely the varnish maker should be consulted.

CYLINDRICAL LAND STEAM BOILERS OF WELDED CONSTRUCTION (OTHER THAN WATER-TUBE BOILERS)

No. 2790 : 1956. Price 12s. 6d.—This new standard applies to direct fixed and waste heat cylindrical and loco-type boilers of fusion welded construction for land purposes, and they are classified in the standard as Class I, Class II and Class III boilers. There are no limits to the application of Class I boilers, whilst Class II and Class III boilers are for use within specified design pressures.

Requirements are specified for materials, construction and workmanship, scantlings, and inspection and testing.

Three appendices deal with general requirements for the metal-arc welding of mild steel, typical methods of attachment for standpipes and pads, secured by welding alone, and approximate metric equivalents.

ARCHITECTS', ENGINEERS' AND SURVEYORS' BOXWOOD SCALES

No. 1347 : 1956. Price 5s.—The principal differences between the original standard and this revised edition are that the scales used by architects and engineers and by quantity surveyors are now given in one publication, and that all the information for each scale is given in one item of a table. This new arrangement has made possible the allocation of a reference number to each scale. Advice on a standard method of ordering, with a typical example, is given. The standard lists ninety-four scales in common use, and full details of the figuring for each are given in a table. The differences between open and fully divided scales and foot and fractional foot and inch and fractional inch scales are illustrated, and figures showing the Armstrong and quantity surveyors' scales are also included.

Dr. Glasgow's Contributions to the Gas Industry

A special lecture in memory of the late Dr. Arthur Graham Glasgow, arranged by the Institution of Gas Engineers, was presented in London on Tuesday last, March 5. Dr. Glasgow, an outstanding pioneer in the gas industry, died in October, 1955, and the memorial lecture, an abridged version of which is given below, was presented by Mr. F. M. Birks, a past-president of the Institution.

DR. ARTHUR GRAHAM GLASGOW was born at Buchanan, Virginia, in May, 1865. He graduated from the Stevens Institute of Technology in 1885 and immediately joined the United Gas Improvement Company of Philadelphia. This concern was quite unique in any country of the world as, although engaged in the supply and manufacture of gas-making plant, it controlled and operated some forty gas undertakings. The young engineer was secretary and manager, Lewiston Gas Light Company, 1886 ; engineer, Kansas City Gas Light and Coke Company, 1888 ; and was appointed general inspector to the United Gas Improvement Corporation, 1890.

In order to appreciate his life's work, it should be viewed against a background of the problems that beset the industry at that time both in Europe and the United States of America. For nearly sixty years, the industry in this country had been mainly engaged in producing gas for lighting purposes, but, having been without serious rivals during this time, it would be no exaggeration to say that many boards of directors and higher executives of undertakings had become quite complacent regarding problems of supply. When, in about 1878, the practicability became apparent of the supply of electric light to the public, they suddenly began to take their responsibilities very seriously, but found themselves faced by several worries.

The general increased prosperity of the country was reflected in the gas industry by steadily increasing consumptions, which somewhat lessened their anxieties. Nevertheless, the low price of coke and the greater quantities made, resulted in difficulties in selling at a time when its smokeless properties did not attract the ordinary individual. The trouble gradually got worse until, in the '80s, recourse to exporting surplus stocks was instituted.

In order to be less dependent on the lighting load, serious encouragement, previously actively discouraged, was given to cooking and heating, &c., by gas and also to the industrial load. At this time the cheapest and most convenient form of obtaining small power supplies was by means of gas engines, and the supply of gas for this purpose became quite an important part of the industrial load.

The peak load was also causing anxiety ; this was somewhat unpredictable as it was caused by what to-day we would call " smog," but this was a more virulent type than is experienced nowadays. The peak was not due to the heating load as it is to-day, but almost entirely to lighting. In summer, the consumption was for about eight hours during the night and in winter about sixteen hours. The holders were filled in the daytime to tide over the night consumption. During black fogs the lighting continued throughout the twenty-four hours, so it will be appreciated that it constituted a very severe peak, particularly when the fog continued for several days.

It was customary to keep carbonising plant under slow fire for such emergencies, while it was usually considered that the holder capacity should be equal to the output of the maximum day. Even so, in order to tide over such difficult periods, it was not unusual to " over-pull " on the retorts and to drop district pressure.

The problem was the great difficulty of keeping up the candle power of the gas, due to the growing shortage and high price of cannel coal, whereas, in order to compete in the future with the young electrical industry, it would be essential, however difficult, still further to improve the brilliance of the luminous gas flame.

Many ways of dealing with this problem were considered and in some cases tried out. Oil was available from the shales of Scotland and the oilfields of Russia and America. Making gas from oil was nearly as old as making it from coal. At the period under review, many railway companies had plants that produced about 70 cubic feet of 62-candle-power gas per gallon of oil passed through the retorts. This gas, contained in steel cylinders at a pressure of some atmospheres, was used for lighting railway coaches, so it was apparent that this might be a method of improving town gas of 15 to 16 candle power of the so-called common gas or 21 to 22 candle power of the better qualities. Oil was introduced in certain of the retorts laid off for this purpose either by letting it run in or injecting it into tubes in the retort by means of steam. The quantity of steam was limited to that required to keep the tubes clear, as it was noticed that too much reduced the candle power. Oil was also mixed with the coal ; sometimes the mixture was ground. Benzole, butane, carburine and several other materials were tried.

The water gas reaction had been well-understood for many years. The first record of a practical carburetted water gas process in England was in 1831, when George Lowe patented a process whereby hot coke was discharged from a horizontal coal gas retort direct into a water gas generator and then intermittently heated by natural draught and steam to form water gas. It is interesting to note that the patent states that the gas should be enriched by saturating with the vapour of essential oil or other illuminating materials. None of these early suggestions could materialise into commercial plants until supplies of mineral oil became available for enriching later in the century.

In the United States of America, conditions were very different, because it was then possible to enrich it economically, as large supplies of mineral oil were being found and were nearly as cheap as coal, In parts, anthracite was freely available ; this coal, being natural coke, was suitable for gasifying, but not for carbonising.

From 1874 onwards, many oil-enriched blue water gas plants had been constructed. These consisted of three broad types :

(1) Retort processes, namely those in which the carbon for the decomposition of the steam was contained in retorts externally heated.

(2) Generator processes, namely those where the carbon for decomposition of the steam was contained in a refractory-lined vessel, the coke being blown by air until white hot, when steam was subjected to the hot coke. The resultant blue water gas was enriched by passing it into a second vessel heated by a separate fire.

(3) A modification of the second class, in which carburetted water gas was made in a single operation ; the gasification and fixing of the gas taking place simultaneously with the manufacture of water gas by means of a superheater filled with refractory checker bricks and heated by the blast from the generator.

To the last of these belonged the Lowe process invented by Thaddeus Lowe, born in 1832. He had many inventions to his credit and finally, in 1897, produced the new Lowe coke oven system of the by-product type. This plant, constructed by Lowe in 1874, was the forerunner of the modern carburetted water gas plant and comprised, very simply, a water gas generator and single superheating vessel for oil cracking, a wash box with water seal, a gas scrubber and a condenser.

At this time, the main outlet for mineral oil was as paraffin for the lamps of China and the rest of the world. The oil used on the water gas plants was either the residue from this distillation, sometimes with the lighter spirits added back, or crude oil. As a gas of twenty-nine to thirty candle power was often called for, necessitating a consumption up to 4½ gallons of oil per 1000 cubic feet of gas made, considerable difficulty had been experienced with the earlier Lowe plants due to the deposition of lamp black in the checker brickwork ; this caused the plants to cease gas making for long periods, in order to clear the brickwork. The greatly increased thermal efficiency of the Lowe plants over the earlier ones was, to some extent, nullified by the sooting-up trouble.

Dr. Alexander Crombie Humphreys, born in Edinburgh in 1851, was the son of a Doctor of Medicine, who moved to Boston, U.S.A., in 1859. He became chief engineer of the Pintsch Gas Lighting Company, of New York, and in 1885, was made chief engineer by the United Gas Improvement Company of Philadelphia. He started at once to recruit technical graduates and one of the first was Glasgow, who was employed as a cadet engineer on special assignments, as an assistant in various gas works, as manager and secretary of Lewiston-Auburn Gas Company, as personal assistant to the general superintendent, as engineer of the Kansas City Gas Light and Coke Company, and as general inspector of manufacture at all the United Gas Improvement Corporation's Works in 1890.

Fortunately at this stage the various interests representing the Lowe process were consolidated, absolute control passing into the hands of the United Gas Improvement Company, when, under the general superintendence of Humphreys, engineering skill of a high order was brought to bear on these problems ; henceforth the technical and practical side of the process received unremitting scientific attention. In the forty works of the company, at some time or another, every known process of making water gas had been in use, so Humphreys had a unique opportunity for quickly obtaining and analysing results.

He, after a short while, introduced his double superheater system called the Improved Lowe system. In this arrangement, the water gas leaving the generator entered the top of the first superheater (afterwards called the carburetter), the oil sprayed downwards at the centre of the top uniformly covered the whole cross-section of the gas stream and, as the gas travelled downwards, the lighter spirits could not flash off faster than the heavier constituents. A further great advantage to this system was that each vessel could, by adjustment of the secondary air to burn the combustible blow gas, be regulated to the most suitable temperature to ensure perfection of both carburetting and fixing the gas, as each vessel had a separate supply of air.

This was the general overall position in 1889 when the court of directors of the Gas Light and Coke Company sent their chief engineer, George Carless Trewby, over to the United States in order to ascertain whether American practice could be adapted to conditions in the United Kingdom. There are no records of what arrangements he was authorised to make or what he did on his own ; but the first plant of 1,000,000 cubic foot capacity per day, consisting of two 500,000 cubic foot per day sets, was ready for shipment in October, 1890, although authority to order this plant had not been granted until August 1890. Glasgow was charged with the task of getting this plant successfully into operation, and succeeded in getting it to work in the very early days of 1891.

Later in 1890, another plant was ordered from the United Gas Improvement Company, Philadelphia. At that time, apparently, it was thought that, as the blow and make were of equal duration, the plants should be ordered in two halves, which were intended to work alternately. Thus, the two orders for 1,000,000 cubic foot capacity plants did, in fact, consist of four 500,000 cubic foot sets. The 1890 orders to America totalled 2,000,000 cubic foot capacity and were subject to the free licence for the use of patents, if any, in respect of further plants.

Throughout the whole of the negotiations, it was clear that all concerned were doubtful as to the best oil to use for carburetting. The appalling number of fatal accidents in England caused by exploding paraffin lamps had already resulted in legislation to make the storage of oil safer by bringing in stringent regulations limiting the flash-point to above 73 deg. Fah. It was, therefore, only considered possible to use Russian oil,

which had the added advantage of being somewhat cheaper. The two original plants had been arranged to be fitted with annular oil heaters around the hot gas main outlet from the superheater. In September, 1890, The Gas Light and Coke Company placed orders for 10,000 tons of Novorossisk Russian crude oil and one cargo of American oil.

The first section of the plant appeared to have started up with no difficulty, but it was soon evident that the Russian oil was unsuitable ; the time taken to clear the carburetter and superheater of lamp black reduced the capacity of the plant to about half. With so much stock of this oil on its hands, it must have been very disconcerting to the company, but the solution was rapidly found by a second distillation from which the heavy oils and pitch were discarded. This appears to have constituted what was afterwards known as gas oil, and soon this fraction became freely available, the oil corporations being thankful to find an outlet for what had previously been a drug on the market.

In May, 1891, at the summer session of the Institution of Gas Engineers, Trewby dealt with this plant in his presidential address and papers were read by Glasgow and Thomas Goulden. The latter was the senior assistant at Beckton and was responsible for running the plant. He was by far the most able of the younger technical staff at that time. He became engineer at Beckton in 1897, deputy chief engineer in 1901, and chief engineer in 1904.

During 1891, the Gas Light and Coke Company was desperately looking for large plant additions and, as it appeared that Humphreys had failed to persuade the United Gas Improvement Company further to extend beyond the United States, for the reason that its chief objective was to acquire existing gas works and profit by the economies introduced rather than install the Lowe process in gas works owned by others, the undertaking had to decide how it could obtain further plant manufactured in the United Kingdom.

Glasgow must have been impressed with the possibilities of carburetted water gas in Europe and on his return to the United States his enthusiasm was undoubtedly shared by Humphreys, who had been thinking on similar lines and so immediately agreed when Glasgow invited him actively to join in a venture abroad. They formed the Humphreys and Glasgow partnership and established an office at 9, Victoria Street, Westminster, on May 12, 1892, with total resources of 750 dollars.

It was about this time that Humphreys introduced the down run in the United Gas Improvement plants. This only increased the thermal efficiency by the reduction it made in the combustible fuel lost with the ashes ; its purpose was to ensure that the bottom of the fuel in the generator was always at such a temperature that ignition was certain. It had been found, particularly with American anthracite, that after long runs the bottom layer of fuel had become sodden with condensed steam to such an extent that ignition was not recovered during the whole of the blow. The disadvantage with the system was that it necessitated two large valves in the gas offtakes which were subjected to considerable temperature and, as the plants tended to become larger and larger in size, were heavy and slow in operation.

The young firm met with immediate success ; it worked in closest collaboration with the United Gas Improvement Company with which it had a valuable reciprocal agreement whereby all patents, improvements, drawings, and working details reverted to both parties.

The first order obtained was for Copenhagen, and the first plant built in the United Kingdom was for the Belfast Gas Company and consisted of two sets each of 750,000 cubic foot per day capacity. Up to this point, everywhere the evidence points to the driving force behind the use of carburetted water gas in the United Kingdom being the desire to improve the candle power of the gas. The desire to obtain a better artificial light in general was also strong in America ; it was at this time quite easily met, as a number of the gas undertakings supplying nothing but carburetted water gas were able to maintain a quality of 30 candle power. This must have appeared very attractive to the British gas industry. Amongst several other attractive features of the new system of gas making the chief ones were, first, ability to increase the candle power ; secondly, to regulate the coke market and thus obtain higher prices, and, thirdly, to meet the heavy peak consumption during fog.

At this time the incandescent mantle was known, but was not thought to be of any practical use because of the fragility of the mantle ; it was, however, steadily improved until in a few years it came into almost universal use, thus eliminating the interest in gas luminosity. Carburetted water gas was, of course, accepted as a means of easy regulation of quality or, as one gas engineer naively expressed it, being of use when the coal gas exhauster man has been too much in earnest. Within a few years, the use of carburetted water gas to regulate the coke market was adopted on a wide scale. It was not, of course, possible to do this and to have the plant available for peak purposes, but using it to regulate the coke for sale during the summer months proved effective for many years until the formation of coke-selling organisations improved the quality, the demand and the price of the coke so that the practice was no longer so necessary

The advantage of flexibility enabling this type of plant to meet heavily fluctuating demands proved in the end to be the most important factor. It is difficult to assess the effect on consumption of the improvement of load factor due to the increased proportion required for heating, cooking and industrial purposes, but, although this was great, the increasing use during the period of water gas to meet peak consumptions, together with this improved load factor, did in fact result in the Gas Light and Coke Company not requiring to install any additional gasholders for a quarter of a century.

Although in the course of a few years the widespread use of the incandescent mantle eliminated the interest in gas luminosity, it took nearly a generation and a world war before the gas standard was changed from candle power to calorific value.

These other advantages ensured a steady and very great increase in the use of water gas and the young firm entered a phase of " expansion." Improvement was only made in detail and for over twenty years the general design remained substantially the same. This period enabled the firm gradually to recruit an able staff which was able to take over the responsibility for detail which, in the early days, had rested entirely on Glasgow's shoulders. In 1894, Humhreys left the United Gas Improvement Company and opened up the American office of Humphreys and Glasgow, which he operated until 1902 when he became President of Stevens Institute of Technology.

The first world war gave a powerful impetus to means for improving efficiency in all spheres of activity and the firm now entered a phase of " thermal efficiency and automation." From then onwards the plants which had for so long retained their original features suddenly began to assume new shapes. In 1916, the first waste-heat boiler was installed ; thus, the large amount of heat that previously escaped from the stack during the blast was harnessed to produce steam which was so important a part of the process.

For some years, the capacity of the plants had been growing and on the larger ones the down-run and stack valves were becoming heavy to operate, more particularly as this operation had to be performed accurately against time. On some of the larger sets, an early servo system was applied, the necessary power being provided by a hydraulic system. The operator was thus able to control all valve movements while seated at a desk. The small levers of the hydraulic servo valves were light to work and were fitted with neat and effective interlocking arrangements so that it was impossible for the operator to make an incorrect movement of the main valves. This arrangement opened the way to automatic working and in 1919 the first plant in which the various valves were operated automatically was installed at Brighton. The introduction of this gear enabled big improvements to be made as the operators are not only relieved of the laborious work in operating the valves, but the timing is much more accurate than it is possible continuously to expect from manual working. In 1922, self-clinkering grates were introduced ; these are of two types, the dry and the wet. The advantage of the former is that it allows much heavier pressures to be used on the blast than the latter and thus increases the capacity of the plant, or allows it to work at high capacity with the smaller sizes of coke. A year later, the charging of the generator was made automatic. The introduction of these mechanised operations resulted in an almost complete reduction in the time previously lost in carrying them out and thus makes the process as near as possible to a continuous one.

In 1942, a considerable improvement to the cycle was introduced : the down run which had been in use for so many years was abandoned and a back run substituted. This enabled the large hot-gas valves, previously referred to, to be eliminated, as the blue water gas made when the run is downwards is led direct to the water seal and by-passes the carburetter and superheater. This means that during this part of the cycle—some 25 per cent—the gas is not carburetted, so that the injection of oil in the up-run part of the cycle has to be correspondingly increased.

The economy obtained is due to the steam being introduced—while the run is downward—not at the top of the generator, but at the top of the superheater ; during its passage through the hot refractories, it transfers a great deal of the heat stored therein back into the fuel bed. This run downward every cycle keeps the fuel bed in a better average condition than the old down run, which was only used every three or more cycles.

It must be appreciated that when the down run was introduced by Humphreys the superheaters were dealing with twice the quantity of oil that is in use to-day in this country. The heat returned back to the generator with the modern cycle is at the expense of the steam raised in the boiler. It has to be borne in mind, however, that the fuel in the generator is costly coke, whereas any deficiency of steam is made up from boilers using low-grade breeze as fuel.

The latest development is the high peak process, whereby increases up to 40 per cent of the rated output can be obtained to meet exceptional demands. During the blow, blast gas is by-passed direct from the top of the generator to the water seal and into the gas mains. A special combined oil sprayer and burner replaces the normal oil sprayer in the carburetter top. As the combustible blast gas is no longer available to be burnt in the carburetter, it is necessary to burn oil in order to replace the heat requirements of the checker brickwork. During the run, the oil input has to be considerably increased in order to bring the low calorific value of the blast gas so used up to the required calorific value of the rest of the make.

It may be of interest to give the history of the first two plants installed in this country. Beckton, because of many factors, is a natural site to make water gas. It was remodelled and extended by Humphreys and Glasgow in 1899, and from then on, until the second world war, was rebuilt, the capacity of the units increased, and every improvement added as available.

After hostilities ceased, an entirely new plant was built which embodied every refinement possible to ensure maximum economy in working. Any one single generator has an output greater than all the ten combined that were installed up to 1891.

Kensal Green, on the other hand, by a series of circumstances, has always been an unfavourable site for the manufacture of water gas, due mainly to the heavy demand for coke in the district around. Some time about 1905, the down run was added to two of the sets. Waste-heat boilers were installed to each set in 1920 when the down run was added to the other four sets. Apart from these additions, it remains in almost its original condition and is now probably the oldest working water gas plant in the world.

In 1930, a Doctor of Science degree was awarded to Dr. Glasgow by the Washington and Lee University. It has been said that he revolutionised the gas industry in the Eastern Hemisphere, his professional attainments were of the highest order, the staff of his concern were inspired by him to take the most meticulous care in details, and the whole success of the business can be attributed to the confidence he inspired.

Heavy Precast Concrete Structural Work

OVER the past few years there has been a trend towards the more widespread use of precast concrete for fairly heavy structural work. This trend is well exemplified by the three structures briefly described here. They show that precast structural units—often prestressed as well—are used with weights of the order of 10 tons for normal structural work, and in special cases, like the railway footbridge described below, heavier units are practicable ; in that case the main beams weigh between 30 tons and 35 tons each and span up to 86ft.

Factory at Stratton St. Margaret.—On February 28, a paper was read by Messrs. D. H. New and R. Sanders at the Institution of Structural Engineers on the precast concrete frame for the main building of a new factory for the Pressed Steel Company, Ltd., at Stratton St. Margaret. The factory has production buildings covering 300,000 square feet. The accompanying illustration shows the structural work in progress on the assembly shop, and the press shop. The assembly shop has precast north light framing. The columns of the press shop carry roof beams spanning 60ft and giving 40ft of headroom, constructed in fully bonded prestressed concrete, and also steel crane girders for overhead cranes of 30 tons capacity. The following details of the work are abstracted from the " Structurals " paper.

The superstructure of the main building is precast throughout, having grouted joints, and with a negligible amount of *in situ* concrete. Site shuttering above ground floor level was almost eliminated by shaping the ends of the units so that they could retain within themselves grout or concrete infilling.

Precast reinforced concrete was selected as the main construction material as apart from other considerations reinforcement was readily available. The design then proceeded, taking into account that for speedy erection there should be as few operations as possible. The superstructure framing could be erected in three main operations, i.e. erection of columns, roof beams and purlins. Then roof covering and glazing could proceed immediately, followed by the installation of mechanical services and factory plant. The basic design was simple due to the fact that all columns were arranged as free standing, cantilevered from the base to take wind and crane thrusts, and by virtue of the dowelled joints, roof members could be taken as freely supported. It should be noted that many of the columns were subject to their maximum stress during handling and when subjected to wind pressure in an unbraced condition, i.e. immediately after erection.

Owing to labour considerations it was particularly advantageous to construct the walls in precast concrete panels weighing up to 4 tons each.

The consultant architect, in searching for the best elevational treatment for this material decided to employ alternating coloured rectangles of exposed natural aggregates or mortar, which gave a striking appearance to the completed structure.

For contracts of this nature, when the order is placed before any working drawings have been prepared the order and speed of erection is determined to a great extent by drawing office procedure. Close collaboration between design and construction staff is essential to ensure the maximum production period within the operational programme. This was maintained by the planning engineer on site and the project engineer in the design office. When it is realised that the contract involved some twelve miles of purlins it will be appreciated that details are required early in order that their fabrication may proceed, even before the issue of foundation details. It will be appreciated also, that the majority of drawing office work is in the external wall construction and because of this, details of the more simple internal work were prepared first, in order that manufacture could quickly proceed for the bulk of the columns and roof members. Subsequently, on the site, erection of internal bays was carried out before external work, thus the order of erection was determined by drawing office procedure.

Reinforced concrete was in accordance with C.P. 114 (1948) as amended February 1949, and Highworth Rural District council building regulations. Fully bonded prestressed concrete beams were designed for a working stress of 2500 lb per square inch in the concrete and 74 tons per square inch in the steel. Wind effects were taken in accordance with C.P. 3 Chapter V 1952 Loading ; basic exposure B. Crane surges were as specified in B.S.S. 449, 1948, amended July 1949.

The approximate total weight of precast units was as follows :

	tons
Assembly shop, structure	4340
Assembly shop, wall panels	1030
Press shop and steel store, structure	4210
Press shop and steel store, wall panels	1180
Precast floor units to press shop	4000
Ancillary buildings, structure	1100
Ancillary buildings, wall panels	190
Total	16,050

These units were erected over a period of about fourteen months.

The following items of equipment were used for erection, planning being so arranged that individual machines remained on site, only for the minimum period necessary :

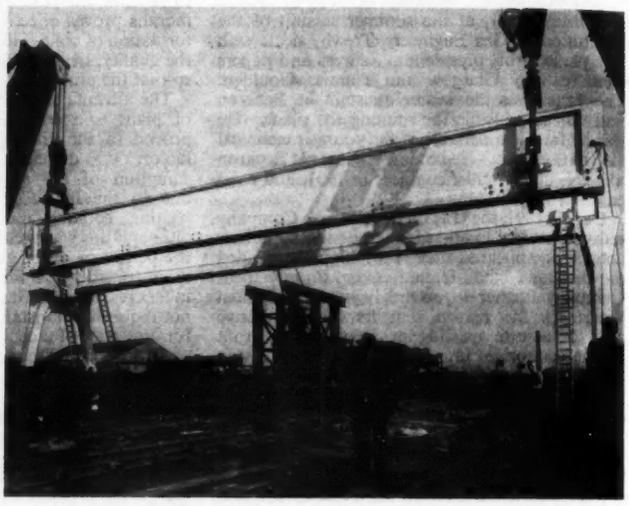
One crawler mounted crane with a 90ft jib for loads between 12 tons and 17 tons for the press shop area.

One crawler mounted crane also with a 90ft jib to handle loads between 5 tons and 14 tons for the ancillary buildings, the outer sections of the assembly shop and steel store, and the cantilevered columns to the loading dock.

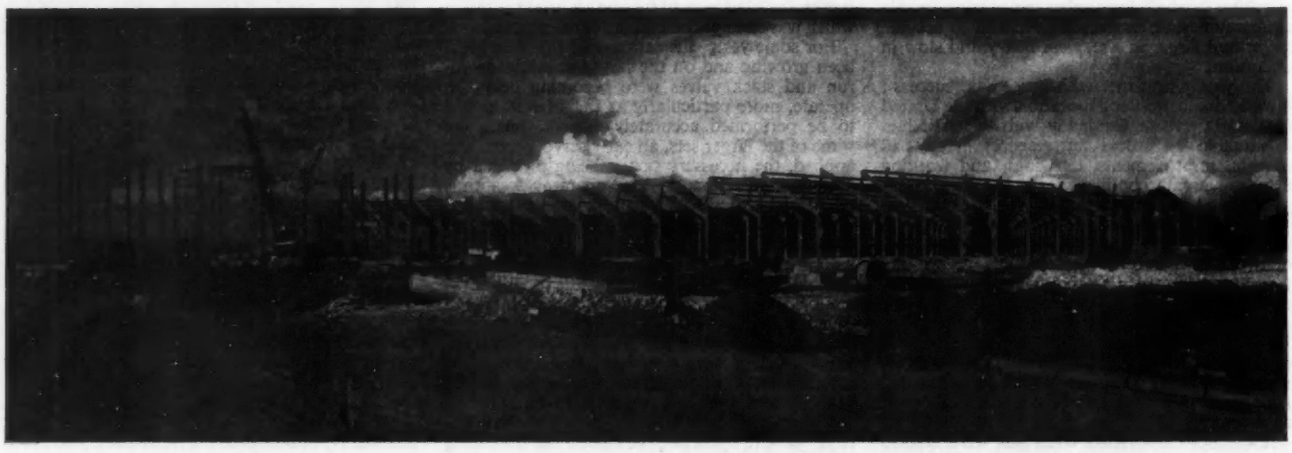
Two ¾ yard crawler mounted excavators with 50ft jibs to handle any loads up to 5 tons, particularly precast wall cladding, the units for which were between 2 tons and 4½ tons.

One 6-ton crawler mounted crane to assist with the erection of the wall units.

The maximum weight and length of precast units used was 17 tons and 53ft but New and Sanders have subsequently been concerned in the use of units of similar weight and



A main beam of the Frodingham-Scunthorpe footbridge being lowered into position on its supporting trestles by two railway breakdown cranes. The structure in the centre of the span was used for steadying the beams during the operation. The holes for the post-tensioning of the spacer beams by threaded steel bars can be seen



Precast concrete structural frame in course of erection for a factory of 300,000 square feet for the manufacture of motor-car bodies

71ft long. They feel that the precasting methods employed have a considerable future in industrial work and can foresee no ultimate limit as regards size and weight. The total approximate cost of the work described, including ancillary buildings and services, was £1,500,000. The main contractor for this work was Holland and Hannen and Cubitts, Ltd.

Ministry of Supply Wind Tunnel.—Another contract involving precast concrete work on a similar scale is being carried out by John Laing and Son, Ltd., for the Ministry of Supply through the Ministry of Works. The contract is for a wind tunnel and involves the erection of a group of large buildings such as compressor hall, plant building with large reinforced concrete bases, control deck, pump house, and ducts for cooling water and an office and laboratory block.

The original design of the buildings, which was for structural steel frames, was amended because of supply difficulties and shortly after setting up the site organisation in April last year, a precasting yard of 30,000 square feet was organised. In four months 17,000 precast units weighing up to 15 tons each were manufactured.

The largest building is the compressor hall, which is 330ft long, 54ft wide and rises to a height of 50ft. It houses two compressors and an overhead crane which is to be test loaded to 80 tons. At the ninth month of the contract the last pour of concrete went into the first compressor block and with the eleven bays of the building erected, aluminium cladding with woodwool backing was being fixed. The structure of the plant building and the smaller wind tunnel building had been erected by the beginning of last month and the reinforced concrete frame of the office block was under way.

Frodingham-Scunthorpe Footbridge.—The lifting capacities of railway breakdown cranes offer particularly advantageous facilities for precast structural work in railway engineering. The Eastern Region of British Railways has just completed a concrete footbridge to the east of Scunthorpe station which is over 600ft in length. The new footbridge has five spans crossing, in all, five railway running lines and twenty-two sidings, with ramped approaches at each end. The five spans of the bridge total some 373ft in length and the ramped approaches are 125ft in length on the Frodingham side and 120ft in length on the Scunthorpe side ; the complete structure totalling about 620ft in length. The bridge has an overall width of 7ft 4in, overall height of 6ft, providing a footway 5ft wide and 5ft in depth from path to parapet. Concrete has been used throughout for the construction of the bridge employing metallurgical super-sulphated acid resisting cement with granite aggregates to produce a dense mix and a finish impervious to industrial fumes.

The bridge consists of pretensioned concrete beams 6ft in depth, varying between 67ft and 86ft in length, supported upon precast reinforced concrete trestles as shown in an accompanying illustration opposite. The beams for the approaches are of reinforced concrete supported on trestles of similar construction and diminishing size from the bridge to the ramp ends. The bridge trestles are 19ft in height and some 15ft wide at the base. The clearance above rail level to the top of the trestle is 15ft 7in.

Between each pair of concrete beams forming a span of both the bridge and approaches, reinforced concrete spacer beams, 4ft 6in in length, 1ft 9in in width and 11in deep, have been placed at intervals of about 8ft. Each spacer beam was post-tensioned by four threaded steel bars passing through holes in the main beams and through the spacer beams themselves. The nuts were tightened, using torque spanners, to 125ft-lb, and the spacer beams were then pressure grouted. The deck of the bridge is formed of hollow pretensioned concrete floor units each 4ft 7in long, 1ft 2in wide and 4in deep, bedded in cement. The bridge walk is surfaced with cambered asphalt.

The bridge was produced in its various sections at the contractor's factory and transported to the site at Scunthorpe. The trestles supporting the bridge were cast as complete units (each between 6 tons and 8 tons in weight) as were the main beams which are between 30 tons and 35 tons each. Erection was carried out on Sundays. The trestles for the bridge were first erected and then the main beams positioned. The main beams were transported in pairs by a special train to arrive on site in time for each Sunday's work. On average, erection of one span took some twelve hours using two railway breakdown cranes to lift the beams from the rail wagons and place them in position.

To avoid any turning or twisting strains being transmitted to the beams in the lifting and traversing operations, special lifting cradles were built incorporating a universal joint in the uprights. The crane positions and traversing arcs for the placing of each beam were marked out on the ground and they were followed during the positioning operations by plumb lines attached to the ends of the beams.

The bridge was constructed under the general direction of Mr. A. K. Terris, B.Sc.(E.), M.I.C.E., chief civil engineer, Eastern Region. The contractor for the work was Dow-Mac (Products), Ltd., and the consulting engineers were Messrs. Rendel, Palmer and Tritton.

Power Station at Williamson Diamond Mines

The Williamson diamond mines in Tanganyika occupy part of a five square mile concession in the Mwadui field near Shinyanga, 80 miles south of Lake Victoria. The main communication link is the railway from Shinyanga, via Tabora to Dar-es-Salaam, 500 miles distant. A power station has been built to provide the energy demands of the mines. The generating plant, described below, consists of nine 900kW alternators driven by diesel engines, one 750kW alternator driven by an open-cycle gas turbine for standby and peak load service, transformers and switchgear.

ONE of the larger East African power stations operated by diesel engines is the privately owned plant which supplies the Williamson diamond mines in Tanganyika. These mines have been developed since 1940 when Dr. John Thorburn Williamson, a Canadian geologist, made a "strike" which was so rich that at first there was no need to broach the main "pipe." The only machines needed initially were some light excavators working the ground for a few feet below the surface, and in the early days the only independent source of power required was a small horizontal Ruston engine.

As the workings developed more power plant was installed and the present installation, which was supplied by Ruston and Hornsby, Ltd., and The General Electric Company, Ltd., consists of nine 900kW engine-driven sets, one 750 kW gas-turbine set, transformers and switchgear.

The five square mile concession of the Mwadui field is near Shinyanga in a dusty, barren plain 80 miles south of Lake Victoria. Shinyanga is linked by rail with Tabora and with Dar-es-Salaam some 500 miles away. The workings form a self-contained unit, almost isolated from the outside world.

Poor communications and the need for reliability and ease of maintenance were the main factors that had to be considered in the design and layout of the power station. Ventilation of the building and protection of the moving parts against dust required special attention. The site of the power house is 4000ft above sea level and shade temperatures up to 100 deg. Fah. are experienced.

The height of the building from floor level to eaves is 30ft, and the distance between engine crankshaft centre lines is 20ft, with one gap of 40ft which serves as a space for work benches, &c. There is a 47ft span between the rails carrying the 10-ton floor-controlled Patterson-Hughes travelling crane. Protected ridge louvres and fan-assisted air inlets ensure good ventilation, and large windows with widely spaced sun traps mounted outside the glass avoid glare and ensure maximum use of daylight. Illumination for night working is provided by G.E.C. fluorescent tubes in industrial fittings, giving an average illumination of twenty-five foot candles in the engine-room and annexes and still more over the switchboard.

A sub-basement annexe with a flat roof runs the full length of the building on the leeward-side of the prevailing wind, the floor level being 6ft 3in below the engine-room floor. In this annexe are the various auxiliaries such as coolers, air-compressors, air filters, and fuel oil purifiers for the engines. On the opposite side is the main switchboard gallery, which is raised 3ft 6in above the engine-room floor and forms a recess to the main engine-room. Immediately behind this gallery, but separated from it by a wall, is the transformer annexe. The tool-room, stores and offices are at one end of the power house.

The walls of the main building are built

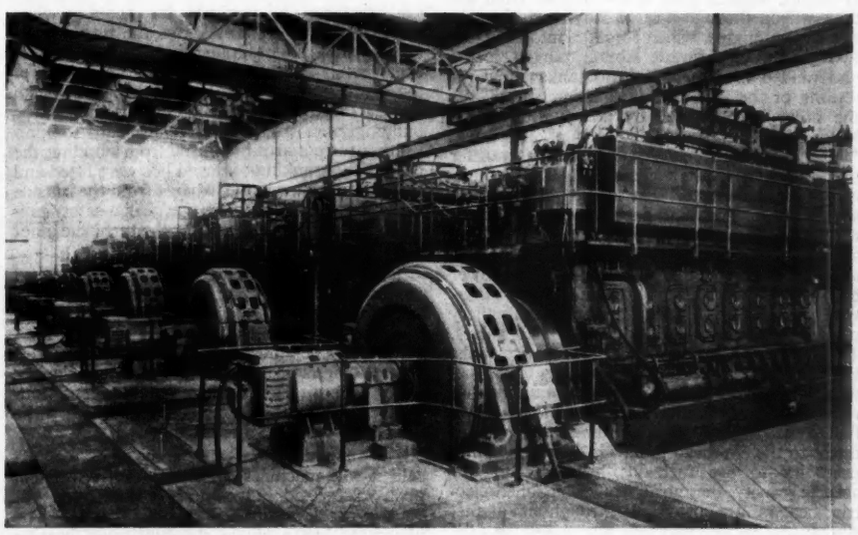


Fig. 1—Six of the nine 900kW engine-driven alternator sets installed in the power station at Williamson diamond mines, Tanganyika

of concrete blocks and the flat roofs of the two annexes are reinforced concrete. The main roof of the engine room is covered with Robertson R.P.M. sheeting, and all floors are hard surfaced with "Salferrocite."

The prime movers are nine 8VLBX Ruston engines, each rated at 1560 b.h.p. at 375 r.p.m. They are standard Ruston four-cycle, direct-injection engines with exhaust turbo-blowers. Because of dusty conditions, open cooling ponds or towers were not considered suitable, and each engine is cooled by a P66 Heenan cooler. These coolers are in the annexe and draw air from ducting led through the annexe roof and terminating in a 90 deg. bend. The discharge air from the coolers is also ducted through the annexe roof, but led vertically upwards to a point higher than the inlets.

Eight 3in by 4in motor-driven CPM Ruston centrifugal pumps are inter-connected at the suction and delivery side; six of them are of sufficient capacity for all nine engines, the remainder being standby. These pumps draw water from a cooled water sump and deliver it to overhead tanks supported 25ft above engine-room floor level on steel frames adjoining the power house. From these tanks water flows by gravity to a manifold pipe running the length of the building at a level above that of the engines; valve controlled branch lines then carry the water to each engine so that the cooling water gravitates through them to a funnel and thence to a hot water manifold, from which branch pipes lead to each Heenan cooler and back to the cooled water sump. The lower-level annexe floor has three main advantages: the suctions of the cooling pumps are almost flooded; flow of the cooling water is by gravity with possibility of after-cooling; and by including a hot water manifold (or gallery pipe) it is possible to use any one cooler with any one engine or to isolate any cooler if required.

Air cleaning is effected by dual Ozonair Ventex air filters mounted on the annexe roof, one set for each engine, and filtered air is ducted to the turbo-blowers. These filters have a butterfly shutter which allows one section to filter air for the engine whilst the other section is cleaned by a flow of cleaning fluid. The necessary motor-driven pumps, dirt trap, cleaning fluid sump and, butterfly operating level are installed in the annexe. To indicate when the change over from one section to the other is required a pipe connection from the inlet air ducting is led to a U-tube gauge for measuring the depression in the ducting, which increases as the filter section in action becomes dirty. The ventilation of the power house is not affected because engine inlet air is drawn from outside the building.

Fuel oil comes in tank wagons from Dar-es-Salaam to a railway siding alongside the brick-built pump house in which are installed two motor-driven pumps, each of 3000 gallons per hour capacity, one pump acting as a standby. A flexible suction hose takes the fuel from the tank wagon through a large Royles strainer to one of the pumps, which forces it into either of two 400-ton Braithwaite storage tanks, erected and welded on site. The two tanks allow for settling of the fuel, one tank being filled while the other supplies fuel by gravity, through a Royles strainer, to the battery of De Laval "4029" purifiers, each with its own transfer pump, which delivers clean fuel to an intermediate tank on a steel structure above the cooler annexe roof. This tank has an overflow back to the storage tanks and a float gauge with reading scale in the engine room. Clean fuel gravitates to a gallery pipe running the length of the power house above the individual engine service tanks, which are fed by branch lines from the gallery pipe and kept at constant level by ball valves. The individual fuel lines from the service tanks lead through the standard engine filters to the fuel pumps. If the fuel supply is of a quality that requires no centrifuging, a separate motor-driven fuel transfer pump (with strainer) delivers oil direct to the overhead tank. In case it becomes necessary to use fuel oils heavier than 0·9 specific gravity, thermostatically controlled electric heaters are provided throughout a fuel system.

Air starting of the engines is orthodox. Lagged exhaust pipes from the turbo-blower lead to expansion boxes placed on the roof of the cooler annexe, with vertical exhaust uptakes terminating in 30 deg. bends pointing away from the building. For the lubricating system 40-gallon drums are placed on a stand at ground level, whence a 2in semi-rotary pump delivers the oil to a storage tank through a Royles strainer. A second semi-rotary pump, situated in the engine-room, delivers the oil through a second Royles strainer to an outlet placed above a drip tray, from which cans of make-up oil are carried to the engines, the "Streamline" filters taking care of the oil in the sumps.

The Ruston "TA" turbine at Mwadui is the first prime mover of its kind in East Africa. It

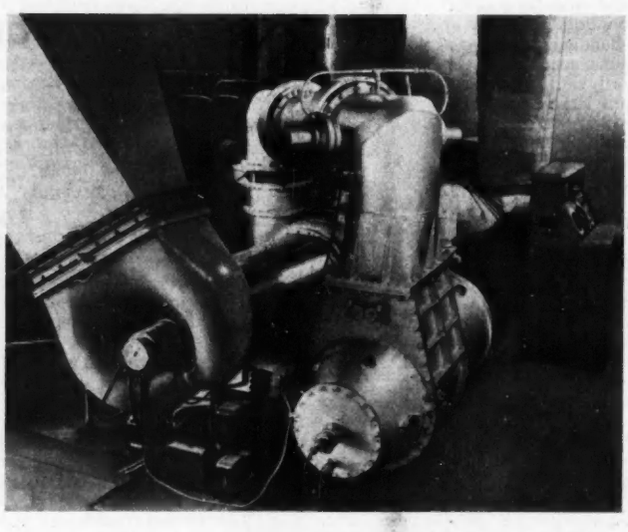


Fig. 2—Open-cycle industrial gas turbine direct coupled to a 750kW, 150 r.p.m. alternator in the power station at Williamson diamond mines

is an example of the company's standard open-cycle design and is used both as a stand-by generator and as a boost during peak demand.

The size of the gas turbine is such that, with only minor alterations, it was housed in the transformer annexe and no extension to the existing power house was necessary. Being air-cooled, no water piping or additional cooler capacity was required. Oil cooling is effected by an air blast cooler mounted direct on an outside wall. The main turbine air intake filters are placed inside the engine-room. They are enclosed with open louvres on the outside wall, so that air is taken only from the outside and not from the engine-room. This obviates any problem of mixing turbine air supply with engine-room ventilation. The filter comprises twenty-seven P800 Microvee panels, which are so arranged that they can be removed for cleaning when necessary. The exhaust leaves the turbine vertically, and the trunking exit is via a flexible expansion joint through the reinforced roof of the engine-room. The vertical exhaust system was the only one which could be employed in the building, and it required special means for preventing torrential rain storms from flooding the base of the trunking; hinged lids were fitted and they completely seal the exhaust from the outside when the turbine is not in use. As a safety precaution, interlocks ensure that the turbine cannot be started whilst the lids are closed.

The control panel carries the governor speed control, emergency stop lever, semi-automatic starting control, alternator and compressor shaft tachometers, and exhaust gas temperature indicator. It also houses the lubricating oil filter. For starting, 24V batteries and a battery charger are installed. This turbine installation is non-recuperative, but a waste heat boiler and heat exchanger could be fitted if required.

The engine-driven alternators are G.E.C. salient-pole machines. They are self-ventilated, open protected machines, each rated at 900kW, 3·3kV, three-phase, 375 r.p.m. The alternator has a single ring-lubricated bearing mounted on sole plates and is coupled direct to the diesel engine flywheel, the coupling being forged in one piece with the rotor shaft. The exciter, which is coupled direct to the alternator shaft, has a single outboard ring-lubricated bearing.

The gas turbine set has a continuous maximum rating of 750kW at 3·3kV, the alternator being driven at 1500 r.p.m. The four-pole rotor was machined from a solid forging complete with the half-coupling. It is designed for an overspeed of 2000 r.p.m. and the completed rotor was accurately balanced dynamically. Cooling is by axial ventilation in which the air is drawn through the machine by a fan mounted on the rotor, the warm air being exhausted to atmosphere. The machine is fitted with a single pedestal bearing with self-aligning rollers. Roller bearings are also used for the exciter, which is flexibly coupled to the alternator shaft.

Power is supplied to the mine at 500V by two 1000kVA transformers, each provided with off-load tappings at 2½ and 5 per cent on the h.v. side. They are standard G.E.C. self-cooled, oil-immersed transformers fitted with conservators. A third transformer, rated at 250kVA, provides a 500V supply for the power station auxiliaries, and six 10kVA transformers are installed for lighting.

The main 3·3kV switchboard in the switch gallery totals thirty-six panels and controls the ten alternators with their exciters, the main and auxiliary transformers and feeders. It is "S.V.D." equipment in which the busbars are air-insulated. Vertical isolation of the oil circuit breakers is by a self-contained interlocked raising and lowering gear. The circuit breakers are rated at 400A with a short-circuit breaking capacity of 50MVA and are insulated for 6·6kV. They are manually-operated with a free-handle mechanism. The shunt-trip coils are energised from a 10A-h, 30V battery with trickle charger.

On each alternator panel is a remote control speed gear which is connected to the engine governor so that any of the sets may be synchronised and connected to the bars by one man stationed at the switchboard. The protective equipment comprises three over-current relays with inverse definite minimum time characteristics, an instantaneous reverse power relay and triple-pole differential protection. Automatic voltage regulators are mounted on the exciter panels. For the feeder units two over-current releases and an earth leakage trip are provided.

Three low-voltage distribution switchboards, each comprising seven panels, control the 500V supply. They are oil-immersed industrial equipments with draw-out oil circuit breakers. The circuit breaker controlling the incoming supply to each board is rated at 1200A, the remaining six breakers having a capacity of 400A. All the breakers are hand-operated and have a short-circuit breaking capacity of 18MVA. Over-current and no-volt protection is provided on each feeder unit, while the incoming breaker is fitted with over-current releases with adjustable time lags. The station auxiliary board comprises a 400A industrial draw-out unit for the incoming supply from the 250kVA transformer, the outgoing feeders being controlled by iron-clad switch fuses rated at 60A and fitted with h.r.c. cartridge fuses.

PROTECTIVE SAFETY SLINGS.—A range of crane slings introduced by Cable Covers, Ltd., St. Stephens House, Westminster, S.W.1, has "Talurit" spliced wire ropes fitted with moulded rubber sleeves. These sleeves serve to protect fragile loads when being lifted and give a good grip on angular contours.

Oscillographic Recording on Southern Region, British Railways

RAILWAY experience shows that on lines where electric multiple unit stock has replaced steam, track maintenance has increased, as compared with that encountered with the original steam service. It has long been held that the axle-hung nose-suspended traction motor is responsible for this effect, because approximately half its weight is carried directly on the axle without the interposition of springs, but there is little authoritative information, either in support or contradiction of this belief. The chief reason for this lack of information is that almost always when a line is electrified there is a very great increase of traffic—often of the order of 100 or 200 per cent—coupled with higher speeds and higher accelerating and braking rates. It is then very difficult to assess to what extent the increased wear and tear of the track is due to the different kind of vehicle with electrification, to increase in traffic, and to higher performance of the rolling stock.

In view of the large electrification extension schemes projected immediately after the war, the Southern Region decided in 1946 to obtain accurate information of the subject before approving the retention of the axle-hung motors used universally on the electrified system up to that time. To determine the effect of an axle-hung motor on the track it is necessary to study the dynamics of the bogie containing the motors in motion on the track. This study involves measurement of forces and movements occurring both within the bogie and in the track. Analysis of the results is much simplified if a continuous and simultaneous record can be obtained of a number of inter-related forces and movements.

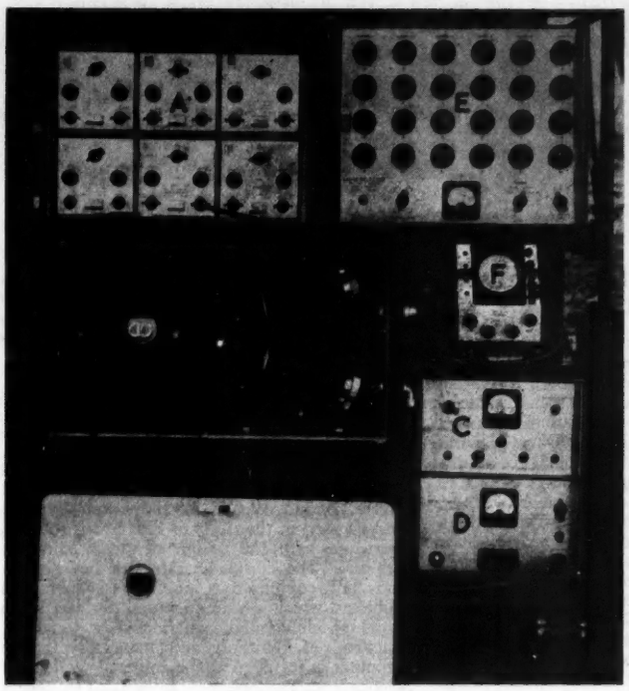
It was decided to adopt the resistance-strain-gauge measuring technique, whereby strains are measured by determining the change in resistance due to elongation or compression of a grid of fine wire attached to the member under strain; forces are measured by calculation of the stress corresponding to the strain measured. Test equipment to meet the particular requirements of the railway was not available commercially and had to be developed—with the co-operation of Savage and Parsons, Ltd., who supplied a six-channel d.c. amplifier with cathode-ray tube display and recording camera with associated apparatus.

A general view of the test equipment is given in the accompanying illustration. The amplifier is basically a six-channel self-balancing push-pull amplifier which will accept symmetrical and asymmetrical inputs. Its input impedance is of the order of 2 megohms and the available voltage amplification is 40,000. The frequency response is uniform from zero to 5000 c/s, and the power consumption is 200W at 220V 50 c/s for the six amplifiers.

The outputs of the six amplifier channels are fed to six cathode-ray tubes having a sensitivity of 1mm deflection for 3V input. The indications on the cathode-ray tubes may be recorded simultaneously on photographic paper moving at a speed of 1in, 5in, 15in or 50in per second, as required. Timing marks are obtained by a high-speed flash lamp, which produces transverse time marks across the whole paper width.

Calibration of the cathode-ray tubes is effected by an oscillator which produces a stabilised 200 c/s sinusoidal voltage, and a calibrated attenuator. The output from the attenuator, which can be adjusted in ten 6 dB steps giving peak-to-peak voltages of 1mV to 1·024V, is fed into the amplifiers and the indication of the cathode-ray tubes for the known input signal is recorded. The calibration oscillator also provides the timing pulses at intervals of one-tenth or one-fiftieth second. Power to operate the equipment is provided by a supply unit of conventional design giving stabilised h.t. and a.c. heater supplies from a 24V/230V rotary converter. When increased stability is required the heaters may be supplied at 6V d.c.

Up to twenty-four gauges may be connected to the equipment, and selected in groups of six for recording by means of a twenty-four way gauge selector provided with a four-position switch. A separate bridge balance circuit is provided for each gauge, giving coarse and fine adjustment. Gauge resistances within the range of 100 to 10,000 ohms may be used. A calibration switch enables a known unbalance of 1 ohm or 10 ohms to be inserted in series with the gauges.



A—D.C. amplifiers. *B*—Camera. *C*—Calibration oscillator. *D*—Power unit. *E*—Gauge selector. *F*—Monitor.

Six-channel dynamic strain recording apparatus developed for use on the Southern Region of British Railways

It was realised from the outset that equipment of this nature could have far wider applications than the investigations of vehicle and track behaviour, and it has in fact been developed to be suitable for many other purposes, some examples of which are given here.

1. The main investigation, that for which the equipment was originally devised, was the measurement of the rail bending stresses set up in bull-head and flat-bottom rails due to the passage of vehicles, the object being to compare bending stresses set up with (*a*) multiple unit electric stock with nose suspended motors, (*b*) multiple unit electric stock with resiliently suspended motors, (*c*) mixed-traffic electric locomotives of the C_0C_0 type, (*d*) main-line diesel-electric locomotives, (*e*) steam locomotives.

As a result of these tests a form of traction motor suspension has been developed for multiple unit electric stock which gives a degree of resilient support of the motor without the complexity of a fully resilient motor and drive. The arrangement makes use of lightweight motors and resilient gear wheels, the resilient support of the motors being achieved by interposing annular rubber rings between a roller bearing suspension tube which surrounds the axle and the motor frame. A bogie including two motors with this form of drive has been built and is undergoing service trials. The effect on the track of this arrangement is being investigated as outlined in the next paragraph.

2. Measurements are being made of accelerations imposed on axle boxes, bogie frames and traction motors due to the passage of a vehicle along the track, with associated simultaneous recordings of displacements at various points on the bogie. The object of the tests, which are in their early stages, is to investigate the riding qualities of different arrangements of bogie. Quartz accelerometers are used for the acceleration measurements.

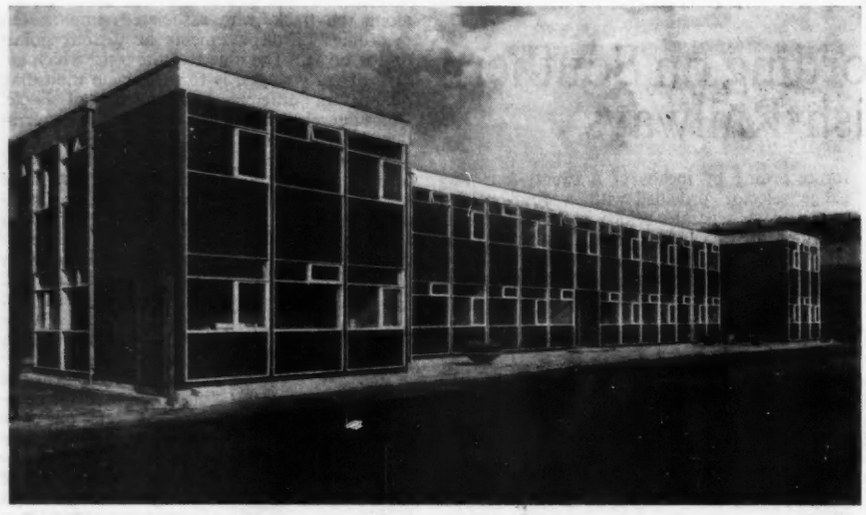
3. Measurements were made of stresses set up in an L.T.E. bogie frame; these tests were carried out at the request of the London Transport Executive and gave useful information regarding stresses under static and dynamic conditions which will be of considerable value when designing new bogies. The tests indicated that all bogie stresses at gauged positions were well within the design factor of safety.

4. The equipment has also been used for development tests on electrical equipment for multiple unit trains including: (*a*) contactor testing under the high fault current condition obtainable on the Southern Region due to the introduction of improved power supplies with the frequency conversion scheme in the London Area; (*b*) traction motor tests to establish the effect of gap running and power supply interruption on the stability of the machine in wear field with either field tap or field shunt; (*c*) observation of the behaviour of equipment protection devices under fault condition and power supply interruption.

These tests led to many improvements being made to contactors and control equipment in service and on order. It was established, for instance, that control protection devices acceptable for use with field tapped traction motors were not necessarily suitable for use with field shunts.

This test equipment which was developed by the chief mechanical and electrical engineer has already proved its worth in a number of investigations which without it would have been much more lengthy, or could not have been carried out effectively. These investigations have in certain cases led to significant improvements in design. In the major investigations into the interaction between vehicle and track, the Southern Region states that effective results could not be hoped for without equipment of this kind; results will only be achieved by systematic and persevering investigation of this very complex problem. The potential benefits, including improved riding and reduced maintenance, however, justify the test equipment.

"TECHNOLOGY": A NEW JOURNAL.—It is with great pleasure and satisfaction that we welcome a new journal published by *The Times* and entitled *Technology*. One of its chief aims, to quote from the editorial in the first number, "is to provide a platform from which industrialists may declare their needs to the public, to Ministers and to university professors, technical college heads and schoolmasters and mistresses." The purpose of the new journal is also to make known to educationalists and through them to the youth of the country the needs of industry for managers, technologists and technicians, and to allow those whose main concern is educational to "talk back" to industrialists. The spirit in which the journal is to be edited is epitomised by the last two sentences of the editorial. "Scientific manufacture is our business, the source of our power, and the means of our livelihood. It is the splendid vocation of our time." It can, we think, be confidently hoped that this new journal will help to raise the status of engineers and other technologists in the eyes of the people of this country.



New office building at Marylebone for staff of the Chief Electrical Engineer of British Railways

New Offices for British Railways Central Electrical Staff

ARISING out of the rapid development of electrification under the modernisation plan for British Railways, there has been an urgent need to afford modern, suitable and centralised office accommodation for the staff of the Chief Electrical Engineer, British Railways Central Staff, B.T.C., who have previously been dispersed in various buildings. The Architect to the Commission, Dr. F. F. C. Curtiss, A.R.I.B.A., was, therefore, asked to prepare a design for a building capable of speedy erection. The site of a bombed building in Melbury Terrace, at the west side of Marylebone Station, was selected as it was conveniently accessible from the Commissions' headquarters at 222, Marylebone Road. The new building illustrated above has two stories giving a floor space of 12,700 square feet.

After site investigations a draft scheme based on the use of the "Derwent" timber system of construction developed by Vic Hallam, Ltd., was selected. Immediately after all approvals for the scheme had been obtained, the order was given for work to begin. A fortnight later, on September 10, 1956, site clearance started and the erection of the structure commenced on November 6, 1956. During the course of the erection, the electrical services followed closely behind with drainage and site works proceeding concurrently. The building was weather proof and the roofing completed on December 10, 1956. Vic Hallam's staff left the site on January 18 by which time the electrical installation, clock and telephone wiring was completed and awaiting the connection of fittings. Decorations, flooring, the installation of all fittings and the delivery of all furniture was completed ready for occupation on February 21, 1957.

The building forms a self-contained unit which now houses the technical staff of the Chief Electrical Engineer, British Railways Central Staff. The Chief Electrical Engineer is responsible to the Commission for the design of electrical equipment and although much of this work is delegated to regional officers, the design and development of electric traction equipment for the single phase 50 c/s a.c. system of electrification is being dealt with centrally. In order to achieve the rate of electrification desired by the Commission, the maximum amount of standardisation consistent with proving equipment, particular to individual electrical manufacturers, is essential. The main components required for the electrification are therefore being purchased centrally as well as centrally designed, and the whole management of the contracts will be carried out in the new offices. In addition to the supply of all equipment for electrification, the office also deals with a number of other matters which require handling centrally, such as arrangements for power supplies, and co-ordination with the Ministry of Transport and Civil Aviation, with the General Post Office and with other bodies who are, or may be, affected by the electrification of the railways.

Analogue Computer at Imperial College

A RESISTANCE network analogue computer has been built by Sunvic Controls, Ltd., 10, Essex Street, London, W.C.2, for the Admiralty and is to be used in the study of heat flow problems associated with the design of steam and gas turbines. The computer can also be used to study more complex heat problems and analogous problems which are represented by the same forms of differential equations—for example, problems of diffusion and mass flow. The computer is installed at the Imperial College of Science and Technology, London. The design of the computer is based on a manually operated apparatus developed by the late Dr. Liebmann, of the A.E.I. Research Laboratory.

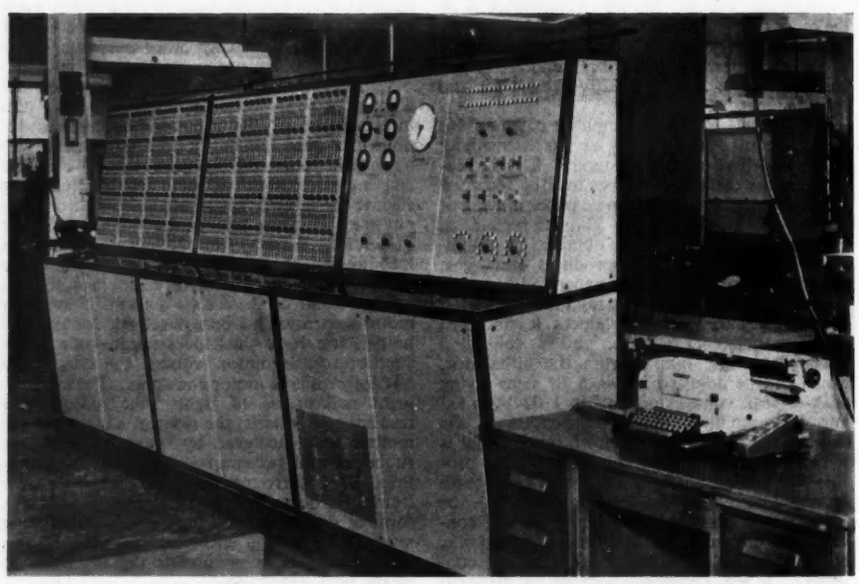
In this method, electrical networks represent the finite difference equations which replace the differential equations governing the problems to be solved. Temperature is represented by voltage, the spatial features of the problem by a network of parallel resistances, and the thermal constants by parallel and series resistances. A solution in discrete intervals of time is obtained by successive readjustments of potentiometers supplying the voltage to the network. This method, similar in character to certain numerical methods though much faster, is very flexible, the thermal constants being adjustable during the progress of the work. It can be applied to problems of considerable complexity, and can be adapted for the solution of heat transfer and heat generation problems, and those where latent heat plays a part.

The computer contains two sets of 200 special single-turn slide wires. The outputs of the first set are connected to the network points through preset potentiometers. The successive readjustments of these voltages feeding the network is achieved by adjustment of the second set of slide wires to the voltage occurring at the network points and, subsequently, by arranging that all these new voltages replace those previously connected to the network. The first set of slide wires is then left free for use in the following cycle.

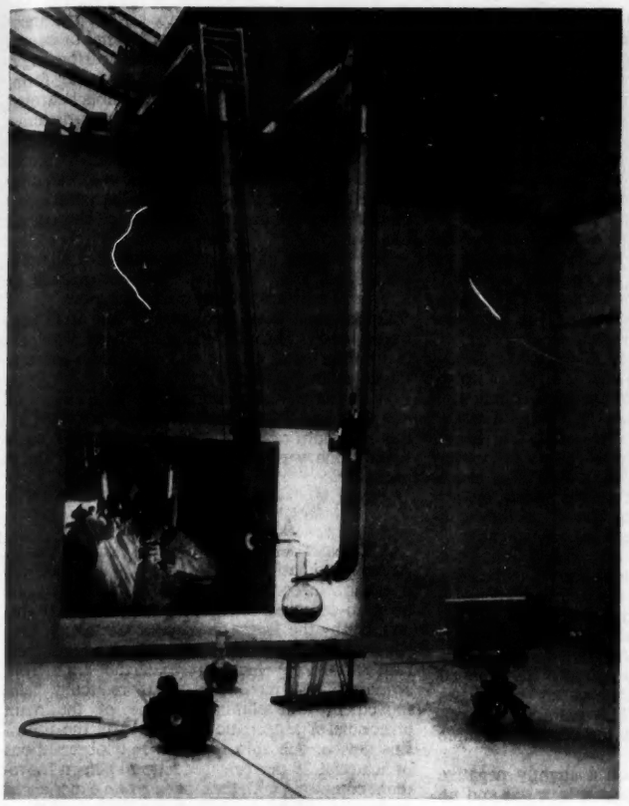
The operation of the computer is completely automatic once the original conditions have been set up. The 200 free slide wires are adjusted in turn by means of a servo mechanism, and the sets of slide wires are interchanged at the end of the cycle, this process being repeated until the required number of cycles, or intervals of time, have been accomplished.

At each step the value of the voltage at the network point is measured by a separate servo mechanism, which is balanced against an accurately calibrated potentiometer. The rotation of the driving shaft of this servo is proportional to the voltage, and attached to the shaft is a "digitising" transducer which translates the angular position into a code, subsequently interpreted by a system of relays into decimal form (three decades). This value, together with the network point identification number, is fed to a solenoid operated electric typewriter. The cycle number is recorded on the typewriter at the commencement of each cycle. Facilities have been included to enable the operator to stop the machine at the end of any balancing operation, or at the end of a cycle, so that the preset values can be readjusted as the experiment proceeds, as is necessary, for example, in the solution of latent heat problems.

As illustrated here the computer is constructed in three units mounted side-by-side; two similar desk units each house the equipment associated with 100 network points, and the other unit contains the main and auxiliary network supplies and control circuits. The network feed resistors are mounted on the front of the two similar desks and the network points at the rear.



Resistance network analogue computer for Imperial College of Science and Technology. It is to be used on behalf of the Admiralty in the study of heat flow problems



A pair of master-slave manipulators in action, observed by a twin television camera providing a stereoscopic image

Remote Operation and Observation

FOR the handling of radio-active or toxic materials, Savage and Parsons, Ltd., Watford, Herts, has developed a mechanical master-slave manipulator which reproduces the movements of the operator's hand at a distance of 6ft 6in. The manipulator is mechanical and worked entirely by manual effort : to reduce the exertion needed, it is made largely from light alloy and all pivots, pulleys, and rollers incorporate ball bearings. The motions are transmitted by torsion tubes, parallel linkages, and cables or steel tapes running over rollers. Looking along the outstretched fingers, the motions are as follows, in such order that each affects those before but not after it :

Gripping : angular motion made linear by parallel linkage and transmitted by wires in tension ; magnification of 2 or 3 to 1 limits weight lifted to less than 7 lb.

Rolling hand : differential movement of bevel gears in " wrist " ; about 500 deg. travel.

Pitching hand : mean movement of bevel gears in " wrist " ; 140 deg. travel.

Yawing hand : rotation of boom, therefore not available if hand is pointed downward ; about 400 deg. travel.

Rise and fall : telescoping of boom—this is the only straight-line action ; 3ft travel.

Move back and forward : swing of boom transmitted by linkage ; travel back 20 deg. to 30 deg., forward 90 deg.

Move side to side : entire manipulator twists.

This equipment was demonstrated to us last week. Friction has been reduced to a low level, movements being started with forces of the order of 1 oz. The very high inertia of the moving parts, compared to the damping inherent, however, calls for a period of familiarisation before accurate movements can be attained. The gripping function imposes some strain—to strike a match, it must be held near the head—and would benefit most from servo assistance. It is intended that, by incorporating power assistance, manipulators to work over a distance of half a mile will be developed.

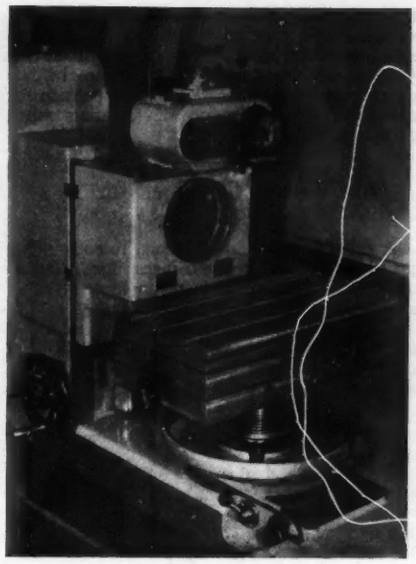
To allow the manipulator to be employed where windows are too small or completely absent, Marconi's Wireless Telegraph Company, Ltd., has devised a system of closed-circuit television. The merely two-dimensional picture of a conventional presentation is inadequate for the control of the manipulator, and therefore a three-dimensional image is developed. Two " Vidicon " cameras, separated by the distance between human eyes, are used together, passing their signals through separate control units to two display screens. One of these control units subjects the image to vertical inversion, and it is viewed reflected in a mirror inclined at 45 deg. to the vertical. This mirror is silvered only sufficiently to give 50 per cent reflection, and the true image screen is seen through it. The two screens are covered by " Polaroid " filters polarised at 90 deg. to each other, and the observer wears spectacles with lenses similarly polarised : thus the left eye sees only the view of the left camera, and similarly for the other. We noted that this system worked well in the immediate vicinity of the point at which the lines of view of the cameras intersected : nearer or farther away, two separate images were likely to be seen despite a deliberate attempt to superimpose them. We are assured that if the system is used only for observation at ranges greater than 10ft, this shortcoming is unobtrusive.

The complete equipment, manipulator and television, is to be supplied to the Atomic Energy Authority's research station at Harwell.

Precision Workshop Projector

A LARGE capacity, high precision workshop projector with a 60in by 40in screen has been developed by Optical Measuring Tools, Ltd., Oldfield House, Bridge Road, Maidenhead, to provide a single instrument with universal application in modern methods of inspection. The equipment, in addition to being designed for inspection of contoured components such as templates, gears, cams, threads, hobs and cutters, also enables blind holes to be measured by surface projection. Recessed work and that produced by die-sinking methods can also be checked on the projector.

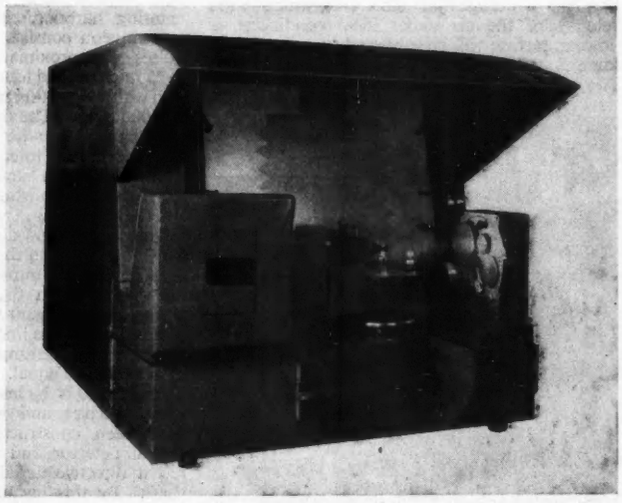
The projector which, can be seen in the photograph reproduced herewith, has a high quality cast iron front base at the rear of which is welded a steel structure clad in sheet metal to form a housing for the optical system. The instrument is supplied with a 20in by 10in table on an elevating mechanism and if required an auxiliary precision table can be provided. This two-part precision table has a movement of 6in at right angles to the optical axis and its lower section provides a ±1in focusing movement. A measuring system utilising gauge blocks and a large diameter micrometer can be fitted to the movement of the upper table section to enable measurement of transverse movement to be made to 0·0001in. A similar measuring system available for the vertical movement reads to 0·0005in.



Elevating projection turret with the 20×, 50× and 100× lenses mounted above the 10× lens

In the optical system there are four gauge projection lenses mounted within one turret and they give a 6in field of view at ten times magnification with correspondingly smaller fields at twenty, fifty and 100 times magnification. This lens turret, shown in our second illustration, has means of vertical and lateral adjustment for lens selection purposes, and if the magnification is changed there is no need to move the workpiece for focusing. The rotary turret of the condenser lenses can be seen in our first illustration and if required an epidiascope projection unit can be fitted in front of this turret. Operation of the epidiascope equipment simply entails the movement of a mirror column into the light path and fixing of a transmission mirror to the lens in use.

Illumination is provided by a 250V, 1000W, high-pressure mercury vapour lamp situated in a housing incorporating a forced draught cooling system. The 60in by 40in clear glass projection screen is supported in a cast aluminium frame and is inclined at 11 deg. to the vertical plane to facilitate viewing. Vertical straight edges fitted to the frame can be adjusted horizontally and

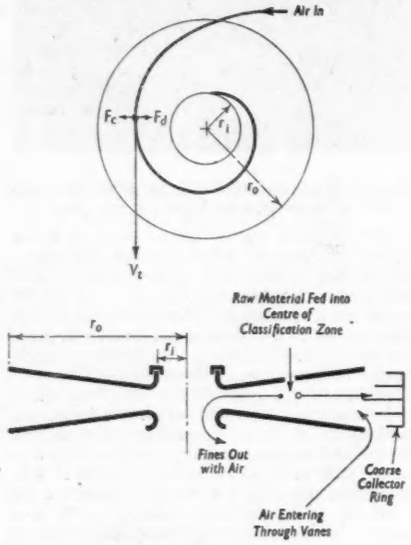


Precision projector with 60in by 40in screen for universal application. The four lenses of the optical system give a 6in field of view at 10× with correspondingly smaller fields at 20×, 50× and 100×

have mounted on them locators by which other straight edges can be positioned, either horizontally or vertically. Provision is made for precise movement to the rear mirror to give fine adjustment of magnification to compensate for expansion or contraction of materials when necessary.

Air Vortex Classifier for Dry Powders

A CLASSIFIER for dry powders, recently introduced by Sharples Centrifuges, Ltd., Woodchester, Stroud, Glos, is made in a series of standard models to handle from 250 lb to 10 tons an hour. It is of air vortex design and is claimed to have a very accurate cutpoint, the sharpness of which is not affected by the throughput rate or size distribution of the feed. To change

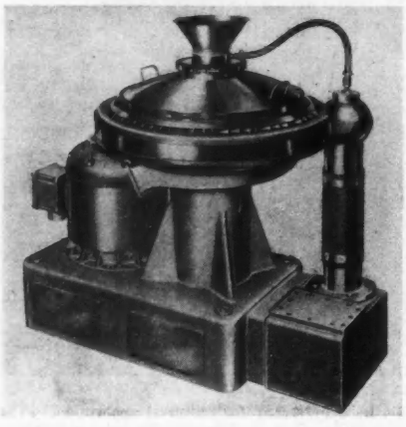


F_c—Centrifugal force.
F_d—Drag force.
V_t—Tangential velocity.
r_o—Outside radius, classification zone.
r_i—Inside radius, classification zone.

Air vortex principle of classification and its application to dry powder classifier

from one cutpoint to another all that is required is the changing of two vane rings and a drive pulley.

One of the new machines is illustrated on this page and the means of applying the air vortex principle of classification can be seen in the diagram we reproduce. In this form of classification air is drawn into a centrifugal chamber from the outside diameter and follows a spiral or vortex path until it is discharged through an opening nearer the centre of the chamber. Owing to its tangential velocity V_t, which is the velocity of the air under ideal conditions, a powder particle will be subjected to a centrifugal force F_c, tending to move it to the chamber wall. The centrifugal force will be opposed by a drag force F_d, induced by the radial inflow component of the airstream. The centrifugal force on the particle varies as the cube of its diameter, while the drag force varies as the first power of its diameter. Thus, if the particle is large enough, centrifugal force F_c will move it outwards, and if it is small enough drag force F_d will move it towards the centre. If forces F_c and F_d are equal the particle will move in a circular orbit. This equilibrium condition determines the cutpoint in an ideal classifier. All particles larger than the equilibrium size will move to the outside and all particles smaller will move to the inside. In this way a powder is readily divided into coarse and fine fractions at a predetermined cutpoint by directing the particles into a suitable collecting system.



Air vortex classifier for dry powders

In the Sharples "Super Classifier," as the machine is known, the powder is brought up to the speed of the air vortex on the rotating top plate before it is fed into classification zone. This movement prior to classification is of particular importance because it can take over 100ft of travel for particles in the size range concerned to be brought up to speed by air velocity alone, and during this time they can possibly be incorrectly classified.

The machine is designed with a constant velocity profile throughout the classification zone, and in this zone the top and bottom plates rotate at the same velocity as the air, so that frictional effects are largely eliminated. There is a constant cutpoint throughout the classification zone, and converging, specially shaped plates increase air velocity as air progresses from outside to inside. This maintains a constant relationship between the centrifugal force and the drag force.

The machine operates on a slightly negative pressure so that powder cannot leak out and no residual powder is left after working. Where there is a relatively high velocity between the powder being classified and contacting walls in the machine replaceable wear plates are fitted.

Microwave Course Beacon

AN Admiralty bulletin issued recently states that a beacon has been developed for the Ministry of Transport and Civil Aviation as an aid to entering harbour in bad visibility for craft which are too small to carry a standard marine radar. The system is an adaptation of the Lorenz landing aid for aircraft and consists of a 3cm radar transmitter mounted at a harbour entrance and radiating in turn from each of two aerials which have beams overlapping in the horizontal plane. This overlapping sector is ¾ deg. wide and the beam width of each aerial is 60 deg. The transmitter is so sited that the line of intersection of the two beams is along the safe course line for entering harbour. The transmission consists of pulses approximately 0·25 microsecond duration with a repetition rate of 1000 p.p.s. The output of the transmitter is switched in turn to each of the aerials in such a sequence that the Morse letter B (— · · ·) is radiated from one aerial and the Morse letter V (· · · —) from the other. The characters of one letter are transmitted during the space intervals between the characters of the other letter, with the result that a continuous signal is received along the line of intersection of the two beams, where the amplitudes of the signals from each aerial are equal.

Reception is by means of a simple crystal-video receiver and headphones. Three types have been constructed, all having the same crystal detector and amplifier. The first type has a directive aerial mounted on a rotatable shaft. By this means, a bearing on the shore transmitter can be measured and a craft so fitted may home on to the beacon. Alternatively, the craft may determine its position in either the "B" or "V" sectors by means of a running fix, and will then be able to lay off the most suitable course to enter the equi-signal or course line sector. A second type of receiver having a directive aerial is made in a portable form, weighing only 4½ lb, for the use of pilots boarding ships, whilst a third type employs a non-directive aerial for use with the course line facility only.

On entering either the "B" or "V" sector with this latter type of receiver, the craft can alter course to one at right angles to the course line for entering harbour and so approach this course line.

The bearing of the course line and the disposition of the "B" and "V" sectors will be known in advance for any particular port.

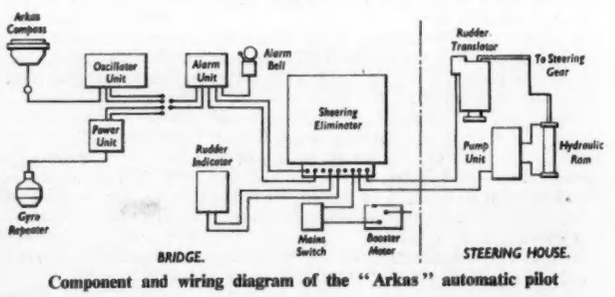
Operational trials were carried out at Fraserburgh and Arbroath, in both cases with the transmitter sited on the end of a mole forming the harbour entrance.

With the transmitter mounted at a height of approximately 20ft and the receiver at about 15ft, the maximum range of reception along the equi-signal zone was found to be between 5 and 7 miles.

Automatic Pilot

A DANISH self-steering system, known as the Arkas automatic pilot, which is designed for operation in conjunction with either a magnetic or gyro-compass, has been introduced in this country by the Decca Navigator Company, Ltd. This unit incorporates an automatic counter-rudder device which prevents the ship from swinging past its course, thus reducing helm movement and eliminating one of the main criticisms of automatic steering. By the use of this device, one ship reported that observations indicated a 25 per cent reduction in helm movement compared with that made by an experienced helmsman. The equipment is also claimed to bring a ship back on to its course after a course alteration with precision, while the link-up with either magnetic or gyro-compass ensures continuous operation of the system during periods of gyro overhaul. To assist steering in heavy seas, the pilot incorporates an adjustment, "Permanent Helm," which provides for the application of weather helm. Through the facility of push-buttons the Arkas pilot can operate as a secondary steering unit and can be used for emergency alterations of course. The arrangement of the system can be seen in our line diagram.

The principle of the equipment is that either compass has voltage applied to it which is carried to two sides of a d.c. amplifier which consists of the sheering eliminator. There is an electrically balanced position: when it is disturbed, either by the ship swinging off course, or when a new course is set, the voltage variations will be applied to the sheering eliminator, which will operate the rudder via relay systems. When the rudder is turned, due to variation of output of the compass, the rudder translator, which is connected to the steering mechanism, will also be turned and, as a result, electrical variations will be sent back to the sheering eliminator and thus counteract the original disturbance. The rudder reaches amidships position, before the ship is back on course, and continues to turn to the opposite helm to a certain degree, thus deadening the swing of the ship.



Component and wiring diagram of the "Arkas" automatic pilot

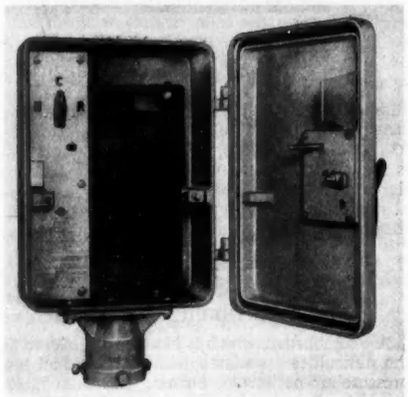
The Arkas magnetic compass operates on the Wheatstone bridge principle and is energised by an a.c. input from an oscillator. Four electrodes at the end of four lubber lines and two silver-

plated segments on the compass card floating in an electrolyte form the arms of the Wheatstone bridge, the output of which is taken to the sheering eliminator. When working on the gyro-compass a potentiometer is used and connected to the centre spindle of a gyro-repeater.

The bridge equipment is designed for bulkhead mounting and the magnetic compass, since it is certified as a steering compass and will fit standard binnacles, occupies no additional deck space. The system can be linked to any design of steering gear and is fitted with a bell and warning light which give the alarm should a breakdown occur.

Dual Point Controller

In railway installations where points are remotely controlled by Centralised Traffic Control or other means, provision must be made, also, for local operation. It is an advantage if the controller can be power-operated locally, with hand operation in emergencies. Both these facilities are incorporated in a new dual-point controller made by the Siemens and General



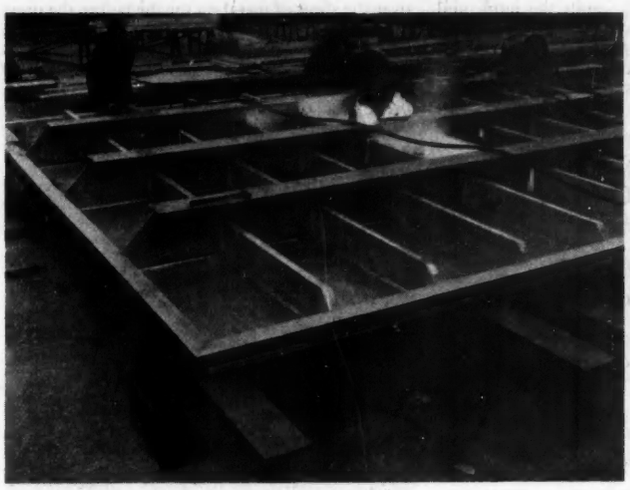
Point controller suitable for remote operation and for local operation either by power or by hand. The door key, the three-position switch and the crank handle are interlocked to prevent mal-operation

Electric Railway Signal Company, Ltd., North Wembley, Middlesex.

A special key enables the hinged door of the controller to be opened to give access to a three-position rotary switch for local power operation, and to a crank handle which can be removed if it is necessary to work the points by hand. When the rotary switch is to be operated the handle is left in position, and the points are thrown by moving the rotary switch to "N" or "R" as required, after which it must be restored to the central position (for remote control) before the door can be reclosed. Preparatory to hand operation the crank handle is removed by first turning it to the left, which makes the necessary changes in the circuit controller contacts ; after hand operation has been completed a cam prevents the door from being closed until the handle has been replaced and moved to its right-hand position. The key is also retained in the lock until the door has been closed and relocked These protective interlocks are of particular value in C.T.C. installations, where a train crew can be given a key in a sealed pouch, which must be surrendered on leaving C.T.C. territory. Production of the pouch shows whether the key has been used ; furthermore, production of the key itself is evidence that the controller has been left with all controls correctly replaced to normal.

Welded Aluminium Deep Tank Hatch Cover

An item of interest fitted on board the 9480-ton deadweight open-shelter-deck cargo motorship "Kepwick Hall," recently completed by William Doxford and Sons (Shipbuilders), Ltd., for the West Hartlepool Steam Navigation Company, Ltd., is the welded aluminium deep tank hatch cover on the second deck, which closes an opening



Welded aluminium alloy hatch cover for deep tank in M.S. "Kepwick Hall"

measuring about 22ft by 15ft 9in. Its weight is just under 2 tons, and the use of aluminium has greatly simplified the lifting and handling of the cover, which in steel would have weighed over 5 tons.

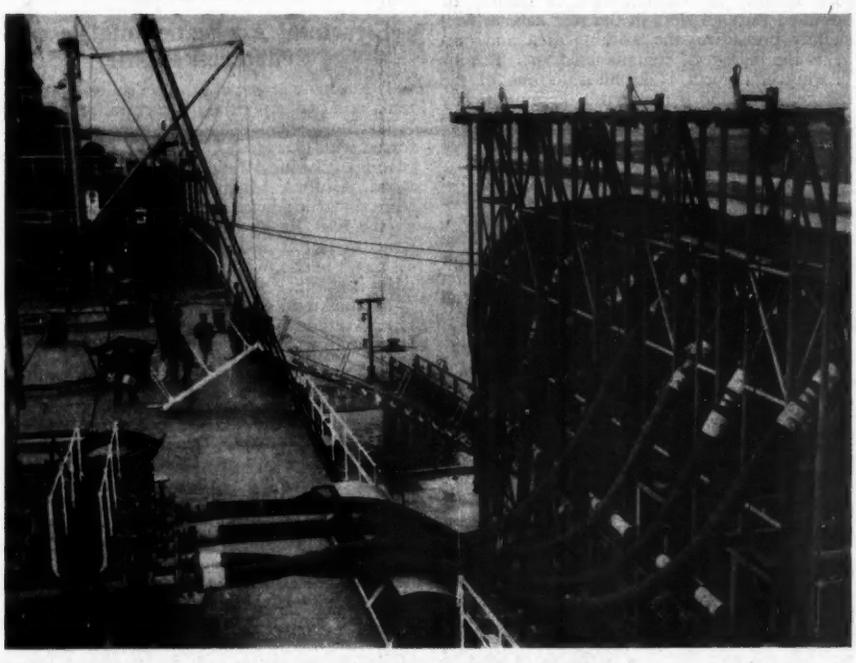
The cover, shown under construction in our illustration, was manufactured by Head Wrightson Aluminium, Ltd., Stockton-on-Tees, from NP5/6 plate and NE6 sections, supplied by Northern Aluminium Company, Ltd., which are now almost standard alloys for welded structures to Lloyd's requirements. The top plating of the cover is 0·44in thick, and the fore and aft stiffeners, spaced 24in apart, are 8in bulb plates as listed in the range of special aluminium welding sections standardised in B.S. 2614 : 1955. Three fabricated girders, 14in deep with 7in face plates, run transversely and are slotted in way of the stiffeners. The cover is secured to the steel coaming by galvanised bolts, a gasket of natural rubber being fitted between the faying surfaces, and the whole of the welding was carried out by the inert-gas metal-arc process.

Hose Handling Equipment

A new jetty which has been commissioned recently by the Mobil Oil Company, Ltd., at its Coryton refinery in Essex, incorporates some hose handling equipment which is designed to reduce the wear and tear on hoses. The system only requires a small number of operators, and the hoses are retained on ten large reels, each of 18ft diameter and accommodating two 30ft lengths of 8in diameter hose joined together by a special short spigot. To operate the equipment a snatch-block is carried to the deck of the tanker, berthed alongside, and the tail of a wire is carried back to the end of the hose, which is then drawn across to the ship's deck discharge valves by means of a winch on the jetty deck. The required length of hose is allowed to run out by the rotation of the reel, which is hydraulically operated, and the oil pumped from the tanker passes through the hose and a radial pipe to the hollow swivel hub of the reel and then into the pipeline connected to the storage tanks.

The open reel operating hydraulic system has a 100-gallon capacity reservoir and is designed for a maximum pressure of 2000 lb per square inch gauge, but the actual operating pressure varies between 500 lb and 800 lb per square inch gauge. Three hoses able to handle 2400 tons of crude oil per hour are generally employed for the offloading of tankers, the remaining seven being employed in loading operations. Altogether it is estimated that about 2,000,000 tons of oil should pass through the jetty per annum.

The jetty, of "T" head construction, is designed to accommodate tankers of 33,000 tons deadweight and provision is made for extensions to cater for tankers of 45,000 tons deadweight. The "T" head consists of a reinforced concrete deck, of jack-arch construction, supported on twenty-four heavily braced steel box piles and sited 14ft above M.H.W.L. with an 18ft tidal range. It is set back 2ft inshore of the face line of the two flanking berthing dolphins. Welded catwalks span the gaps between the head and the dolphins, which incorporate sixteen piles each and consist of a heavy concrete deck and a concrete diaphragm just above low water level, protected by timber fenders. John



Jetty head with hydraulically operated hose reels

Shelbourne and Co., Ltd., built the jetty, and the hose handling system was supplied by the Woodfield Hoist and Associated Industries, Ltd., while Keelavite Rotary Pumps and Motors, Ltd., supplied and installed the hydraulic equipment.

Air-Conditioned Pressurised Assembly Cabinets

WHEN assembling small high precision instruments and similar apparatus difficulty is often experienced in providing completely dust-free conditions and controlled atmospheric temperatures in an open shop. To overcome these difficulties a range of special pressurised assembly cabinets has been developed by the British Manufactured Bearings Company, Ltd., Boscobel, Crawley, Sussex.

These cabinets, one of which can be seen in use in the accompanying illustration, are of all-metal construction and the working area or bench is totally enclosed except for part of the front side, which gives free access for the operator's hands. A constant flow of filtered air admitted through slots in the rear cabinet wall slightly pressurises the working area and prevents the ingress of contaminated air. The air filtering equipment is installed in one of the cabinet sides, and if required a thermostatically controlled electric heater can be incorporated to warm the air before it is blown into the working chamber.

Instrument assembly in cabinet pressurised by a flow of filtered and heated air which prevents the ingress of the dust-laden air

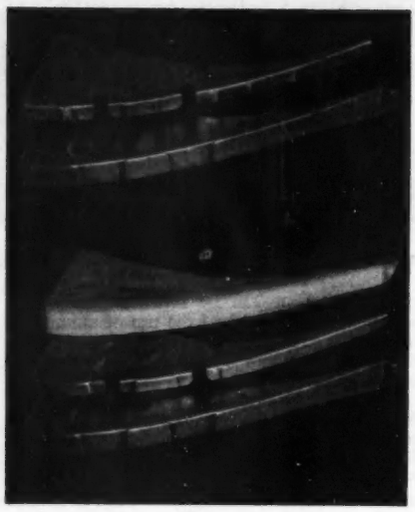
The operator has a clear view of the bench through a large plate glass window and the interior is well-illuminated by fluorescent tubes. Standard cabinets have a bench working area about 36in long by 20in wide. They are available as individual units, or grouped for production work and served, through ducting, by a central air filtering, blowing and heating set.

Rubber Pressing Refinement

AN improvement on the conventional rubber pad press process has been evolved by Short Brothers and Harland, Ltd., to eliminate the need for hand finishing of certain formed components. A limitation of the Guerin process is that the pressure exerted by the rubber is greatest in the direction of closing of the press, and falls off materially in other directions. As a result, wrinkles are likely to be left on steep flanges and this renders the part unsuitable for use directly off the press.

A satisfactory means of preventing these wrinkles has been found to be the use of what is, in effect, a resilient female mould which is placed over the sheet of metal on the die before the press is closed. These moulds are formed from thermoplastic sheet and are sufficiently hard to suppress any minor irregularities as the workpiece is formed, while they will close correctly to the die under the pressure of the rubber. This technique, it is stated, has allowed hand finishing on some formed components to be reduced by half and in some cases eliminated.

The plastic used for the moulds is polyvinyl chloride, and the female can be formed over the male die normally used. In the case of a mould being required for parts thicker than 18 S.W.G., a dummy part is first pressed in soft aluminium and the female formed over the die with the dummy part on it. For the moulds p.v.c., from $\frac{1}{16}$in to $\frac{1}{4}$in thick, is cut to shape and drilled for locating holes. It is then heated and held for ten or fifteen minutes at 110 deg. to 120 deg. Cent. before being moulded on the die in the press. After a few minutes under pressure, the mould form has set sufficiently for it to be trimmed to shape ready for use. It is to be noted that the press locating pins will require to be lengthened by the depth of the plastic female, and the die may need to be packed up to pass them.

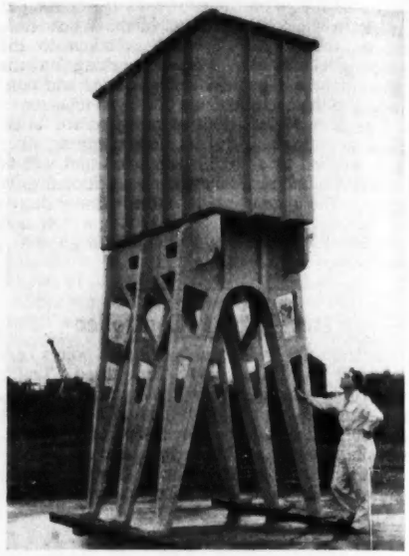


A 26 S.W.G. part formed (above) by rubber pad pressing, and (below) by the use of the plastic mould shown

Structural Application of Glass-Reinforced Plastic

THE accompanying illustration shows a storage tank and its supporting structure built from "Bakelite" epoxide and polyester resins reinforced with glass fibre. The tank was made by Mendip (Chemical Engineering), Ltd., Feltham Road, Ashford, Middlesex, and is intended to store zinc chloride for use in battery manufacture by the Ever Ready Company. The supporting structure is 10ft in height and the tank is 8ft by 4ft by 6ft in size, with a weight of almost 10 tons when it is full.

The tank and structure are built by casting in layers, although the resulting structure is not laminar in its properties. Shapes can thus be arranged to give an advantageous distribution of material for the structural duty required. For instance, the legs of the tank stand are T-shaped with the flange on the inside, where compression is greatest, and the tank itself has a stiff top flange and stiffening ribs on the sides. The percentage of glass fibre in the material can also be varied in a manner not unlike the positioning of reinforcing rods in concrete. The legs of the stand, for instance, which are in compression, have only about 25 per cent of glass fibre, but the cross braces between the legs, which have to resist tensile loads, have about 50 per cent. The structural properties of this material are as yet not fully explored. In this case a working stress of 3000 lb per square inch, which gives a factor of 10 on the ultimate tensile stress, was adopted.



Large storage tank and stand designed for use in battery manufacture

It is estimated that each leg of the supporting structure could, in fact, withstand a crippling load of about 120 tons. But because the material is structurally a new one, there are no standard figures for permissible stresses, nor is there absolute uniformity in the casting process, so the design must necessarily be rather conservative.

Self-Proportioning Oil Burner

AN oil burner, which is claimed to overcome the difficulties associated with conventional low pressure air pattern oil burners, has been introduced by Premier Oil Burners, Lichfield Street, Walsall. The main disadvantages of most existing burners are stated to be: separate air and oil controls, which can result in considerable wastage of fuel should the air control valve be left wide open, coupled with thermal shock; loss of pressure at the burner and poor combustion should the air control be turned down below a certain limit; low turn-down ratio; and lighting up difficulties. It was to overcome these deficiencies that the new burner has been designed and developed under service conditions and results are stated to indicate an average saving of fuel of approximately 15 per cent. Selective automatic air/oil ratio by a single control is incorporated and there is more uniform heating together with more accurate control of furnace temperature. An air valve, of new design, passes a small proportion of uncontrolled air for atomising purposes at a constant pressure and independent of secondary air thus ensuring maximum efficiency throughout the range. Automatic compensation for wear is provided by a spring loaded Vee slot plug valve and there is an adjustable air nozzle to allow flexibility in flame adjustment. The atomiser fitted is of new pattern having twin vortex cups and producing two stage atomisation of the fuel, while the burner has a turn down ratio of 12 to 1. Ease of maintenance is claimed due to the simplicity of the design and also the elimination of smoke.

SUDBURY NICKEL ORES.—A new film in Eastman colour, entitled "Milling and Smelting the Sudbury Nickel Ores," was shown before an invited audience in London last week. Produced by the International Nickel Company of Canada, Ltd., filming was carried out on location at Copper Cliff and other company plants in the Sudbury area of Ontario, Canada. This film is the second in a series and, following "Mining for Nickel," demonstrates the many intricate processes involved in extracting nickel, and thirteen other elements, from the Sudbury ores. The sequence of operations is followed in considerable detail, from the time the ore is magnetically separated into massive and disseminated ores to the final despatch of the metals. The film runs for fifty-four minutes.

Industrial and Labour Notes

Budget Proposals

Following the publication of a report on Britain's economic problems and policies (reviewed in these notes in our last issue), the Federation of British Industries has submitted its Budget proposals to the Chancellor of the Exchequer. In a memorandum which is entitled "Broad Questions of Fiscal Policy," the F.B.I. says that the over-commitment of resources is the cause of inflation. To meet inflation by increasing taxation or by a tight money policy, it is added, is only to postpone a real cure, for the one weakens incentives and encourages wage inflation, while the other puts a damper on the only thing that can increase resources, i.e. investment in the modernisation and extension of industry. High taxation, the F.B.I. declares, kills competitive power and destroys the incentive to create more resources.

The Federation goes on to comment in its memorandum on productive investment, pointing out that all businesses must rely on their retained profits as the first source of finance. For the smaller business, the memorandum notes, retained profits are normally the only source of finance, as such businesses have no access to the private savings of the public generally or through institutional investors. Large and established businesses can supplement their own resources by an approach to the market for additional capital. But to get funds on reasonable terms even they must be able to show a prospect of earnings well in excess of the prospect of dividends. It is, therefore, necessary, the F.B.I. considers, to relieve company profits of some of the present burden of tax.

As to ways of doing that, the memorandum suggests that the fall in the value of money has for many years resulted in taxable profits being computed at artificially high levels. To introduce a permanent solution of that difficulty would take time, but, pending that permanent solution, the F.B.I. advocates restoration of the investment allowances. The memorandum says that while the investment allowances are inadequate in the sense that they do not extend to all fixed assets and because the allowances do not reflect the full extent of the rise in costs, they are nevertheless simple in operation and well understood. The investment allowances should, therefore, be restored, the memorandum declares, and in order to give immediate relief their restoration should be effective as from the date of their suspension. Furthermore, the F.B.I. observes, it is necessary to increase the rates of the allowances in order to enable them to assist in meeting the depreciation problems consequent upon the changed value of money. The memorandum then emphasises that to increase productive capacity it is necessary to increase retained profits, both to provide working capital and investment capital. Company reserves, the memorandum states, must be built up by a reduction of profits tax. The F.B.I. regards this tax as "bad in principle," and says that, pending its abolition, it should, as the Royal Commission on Taxation suggests, be converted into a flat rate tax. The F.B.I. takes the view that the flat rate should not exceed 5 per cent on company profits, with the existing exemptions and abatements for small businesses.

Changes in Wage Rates

The Ministry of Labour reports that changes in wage rates in the United Kingdom which took effect during January resulted in an aggregate increase of about £98,000 in the weekly full-time wages of 664,000 workpeople. Among those who received wage increases were the locomotive running staff employed on British Railways, and bus drivers, conductors and maintenance staff employed by London Transport. The locomotive running staff of British Railways received increases in adult rates ranging from 4s. 6d. to 6s. 6d. a week, according to occupation and length of service, there being proportionate increases for junior engine cleaners. Although these increases were authorised in January, they were retrospective to the last pay week in November 1956. The increases granted to London Transport bus drivers and conductors in January were 7s. 6d. a week, and the semi-skilled and unskilled maintenance staff at garages and depots received 7s. 4d. a week.

The Ministry of Labour has established a new index of rates of wages. Hitherto the index has been calculated on June 1947=100. The base for the new index is January 31, 1956=100, which corresponds with the index of retail prices. In all the industries and services from which information as to wage movements is regularly received by the Ministry, the index number at the end of January was 106 for all workers; the same number applies for the manufacturing industries only.

Export Requirements

The latest issue of *Bulletin for Industry*, prepared by the Treasury, makes some observations on the current year's exports in relation to the balance of payments situation. It points out that in 1956, Britain succeeded in changing her balance of payments from a deficit in 1955 to a "substantial current surplus." Part of this change-round, it is stated, was brought about by the improvement in exports; part is explained by the fact that imports hardly rose at all. Imports did not rise, the *Bulletin* says, mainly because industrial production did not rise either.

But the situation is not satisfactory, of course, from the long-term point of view. A rate of increase in exports is needed which provides a large surplus after allowing for yearly increases in industrial production and imports. From 1948 to 1956, both industrial production and import volume rose, on average, 4 per cent a year. This suggests that, apart from the increase which is at present needed to make the current surplus bigger, a 4 per cent rise in the volume of exports is needed just for normal economic expansion. This, the Treasury says, is only a rough indication. If the terms of trade turn against Britain, export volume needs to rise more than import volume; on the other hand, import-saving developments might mean that a 4 per cent increase in industrial production could, in the future, be managed with a lesser increase in exports.

The *Bulletin* goes on to say that, last year, the volume of United Kingdom exports rose 6 per cent, but adds that "it will require vigorous efforts to maintain this rate of increase through 1957." It is suggested that there are good prospects in the dollar area, which, as a market, the *Bulletin* notes, "is prosperous as never before." Furthermore, it is encouraging that, on the capital goods side of the engineering industry, new export orders were coming in a good deal faster in 1956 than in 1955. But there are indications that last year's big increases to France and to India are unlikely to be repeated, and exports to parts of the Middle East are likely to be difficult. Furthermore, last year's export total was helped by very high exports of ships, which, the *Bulletin* says, "may well not be as high in 1957." It is, therefore, urged that a main aim of policy must continue to be "to keep an economic climate in this country which favours and fosters export expansion."

Coal

On Thursday of last week the House of Commons "took note of the annual report and statement of accounts of the National Coal Board for 1955." A motion, in these terms, proposed by the Paymaster - General, Mr. Reginald Maudling, introduced a debate on the coal situation and prospects.

During his speech, Mr. Maudling said that one of the most important factors in the coal mining industry was the increase in total manpower, which, in the last twelve months, had gone up by 6600 men. Recruitment in the first few weeks of this year had been almost double the rate of recruitment in the same period of last year. Mr. Maudling went on to say that, in 1956, the record output of coal per manshift was not reflected in an increase per man-year, and the number of shifts worked in the year 1956 declined. The most important figure for the economy was the amount of coal produced per man over the course of the year, and there must inevitably be some concern that, despite a further increase in mechanisation, the output per man in 1956 as a whole was down compared with 1955. But, Mr. Maudling added, towards the end of 1956 and in the opening weeks of this year, there had been a welcome improvement. He went on to describe the statistics for coal mining disputes during 1956 as very disturbing. The total amount of coal lost as a result was about 1,800,000 tons, which was a large figure when it was considered what a big investment had to be made in mining to produce 1,800,000 tons of coal. There could be no complacency about the situation, Mr. Maudling remarked, and the noticeable improvement in attendance at the pits in recent weeks was very much to be welcomed; there had also been, he said, a general improvement in activity and morale in the coalfields.

Automation

Last week, the Association of Supervisory Staffs, Executives and Technicians published a statement on the subject of automation. It is a lengthy document which emphasises the Association's opinion that the rapid introduction of automation will only be possible if it is accepted as a national necessity and is planned at national level by a central authority "with sufficient power to ensure that its programme is carried out."

Such an authority, the Association says, would need to determine where and when automation could be economically introduced to increase output, improve quality and lower production costs; to co-ordinate the design and manufacture of instruments, servo-mechanisms, electronic computers and machine tools, and have authority to determine that where automation and other technical installations are justified, they should be introduced with the minimum of delay. The statement then puts forward the view that "the only body possessing sufficient power to enforce such planning in the interests of the whole community is the Government itself." It is therefore urged that a Minister with Cabinet rank should be responsible for the introduction and operation of such planning. Irrespective of the government in power, the Association adds, national planning in the interests of the community is essential now.

There is one section of the statement which comments on capital investment. It says that to permit planning for the introduction of automation, enough capital must be made available to assist companies with insufficient resources to install new, and perhaps costly, equipment. The Association takes the view that sufficient "home capital" will not be available for the purpose, but it says that "any attempt to introduce foreign capital into British industry should be actively discouraged." It considers, therefore, that there is need for a national investment board or corporation with enough capital resources available to help in the realisation of the "Ministry's programme for automation."

Another matter stressed in the statement is that skilled manpower requirements should be based on the proposed Ministry's overall plan for automation, and in apprenticeship schemes related to training for the nature of the skills required. The Association declares that there must be an extension to all establishments employing apprentices of adequate facilities for practical training and a clear training programme to provide the greatest variety of experience. This, it is urged, must be supplemented by a generous theoretical education to permit all suitable apprentices to pass into the higher grades of technicians.

Australian Wire Weaving Industry

THE expansion of the wire weaving industry in Australia to its present annual output of 85,000 tons has been one of the most noteworthy factors in Australian industrial development. The industry was established in 1884 by the firm of Lysaght Bros. and Co. Proprietary, Ltd.—originally a branch of John Lysaght, Ltd., of Bristol—which erected a factory about 5 miles from Sydney on the Parramatta River, for the manufacture of wire netting. The industry is still carried on at the site of this original factory. Beginning with three machines, the company confined its activities during the first twenty years to the production of wire netting, and by 1905 had a yearly output of about 250 tons. It then commenced the manufacture of allied products and within five years was firmly established as a producer of barbed wire and wire nails and had pioneered the manufacture of zinc oxide. In 1929 the Broken Hill Proprietary, Company Ltd., whose steel works, established at Newcastle during the First World War, had been supplying the wire rods and other raw materials formerly imported, acquired a major holding in the company. Planned expansion on a large scale followed, including the installation of modern wire-drawing equipment. The plant and equipment were overhauled and modernised at the end of the war, and this, together with constant improvement in plant practice, has increased productivity to a figure of 1750 tons of wire products per week for the Australian market. All wire is produced from low carbon steel, the high carbon wires being manufactured by Rylands Bros., Australia, Proprietary, Ltd., another member company of the B.H.P. Group. Rods received from the steel works at Newcastle and Port Kembla are stacked in bundles in steel bins under an overhead crane. Storage capacity is 6000 tons, and the crane has a handling capacity of 400 tons each eight-hour shift. The rods are transferred to the cleaning house by transfer trucks with haulage winches. In the cleaning house are six acid tubs, a water spray wash tank, two lime tubs and six rod bakers. A crew of two men clean seventy batches a shift, the batches being from 1·4 to 1·9 tons, depending on the rolling mill from which they came. The cleaned rods are then transported to the wire-drawing machines. There are two wire-drawing mills, the older, heavy mill, comprising four benches of four blocks, and one bench of two blocks, all of which are at present only used for single-hole drawing, the wire sizes produced varying from ⅜in diameter to 8 gauge. Production from this mill is 550 tons a week. The continuous galvanising of wire is performed by unwinding the coils of wire from rotating swifts, passing it through molten lead to regulate its tensile strength, then through a hydrochloric acid cleaning bath, an ammonium chloride flux bath, and finally through a bath of molten zinc, subsequently rewinding the wire on rotating blocks. From these blocks it is stripped in coils for subsequent tying for market. There are four galvanising units, some of which have been modified in the last two years to permit higher outputs and greater operating efficiency. The majority of the galvanised wire is produced for fencing purposes, either as plain fence wire, field fencing, chain mesh fencing, or barbed wire. Wire is annealed for such purposes as netting, weaving wire, hay baling wire, wool baling wire, chain wire, and for subsequent redrawing for soft wires. The annealing capacity at Lysaght Bros. factory is 350 tons of wire a week, and is carried out in fourteen coke-fired, pit furnaces. The wire is packed in either cast iron or heat-resisting steel pots, and after sealing, up to six are placed in the annealing furnace. The annealing cycle is approximately thirty hours.

Nails are manufactured in fifty-four nail presses, capable of producing a range of products from ⅜in brads to 9in deck spikes, turning out their products at speeds between 130 and 450 a minute. After cutting, the nails are transferred to one of ten rumblers for polishing before being packed into cases for market. The barbed wire plant comprises fourteen barbed wire machines, which have been developed over the years. In addition to the "Iowa" wire now being produced, the machines can make a single strand or three-strand, using various gauges of wire and spacings of barbs. The wire is usually wound on to wooden reels, but modifications are being made to permit the elimination of the reels. In the wire netting department are cooling and bobbin sections, a weaving section and a galvanising section. In the weaving of netting from annealed wire it is first necessary to produce wire tubes which are made on tube lathes, and also a two-strand selvedge, which is wound on bobbins. These, together with formed coils of annealed wire, are fed to the machines, which weave the hexagonal mesh. After weaving the netting is taken to the galvanising section, where, after cleaning in hydrochloric acid, it is passed through molten zinc and then wound into rolls for delivery. At present a completely new netting galvanising plant is being installed to replace the existing plant.

Zinc Oxide Plant

With the object of consuming galvanising residues such as zinc dross and zinc ash, which had until then been exported, a zinc oxide plant was established at the Parramatta factory in 1909 for the production of zinc oxide. The bulk of the zinc oxide now being made is still from these galvanising residues, with the inclusion of zinc dust made during the galvanising of steel. Two grades of zinc oxide are produced for the paint industry by the Wetherill Process, wherein the galvanising residues are mixed with the coke fuel and are charged on to furnace hearths, and an air blast is blown through the charge. The zinc vaporises, and is burnt with the excess air to zinc oxide, which is subsequently collected in a filter bag house. A special grade of high purity zinc oxide is made for the rubber trade by boiling electrolytic zinc in clay-graphite crucibles and then burning the zinc vapour to zinc oxide, again collecting it in a bag house. The zinc oxide plant's capacity is 6000 tons a year—more than sufficient to meet any expected Australian demand.

Salt Production at Whyalla, South Australia

No town in Australia has undergone a more rapid industrial development since the outbreak of the second world war than Whyalla, a port in the Spencer Gulf, from which the main supplies of iron ore have been shipped for the steel industry in New South Wales since its establishment over forty years ago. Despite the lack of coal in South Australia, the Broken Hill Proprietary Company decided in 1937 to erect a blast-furnace and to build up an ironmaking industry at Whyalla, which to-day supplies the greater part of the Australian ferrous foundry industry with its requirements of pig iron. From the outset the company was faced with the necessity of transporting coke by sea from its by-product coking plants in the coalfields in New South Wales. The first step was therefore to dredge a deep-water harbour at Whyalla so that raw materials for the blast-furnace could be unloaded mechanically from ships into stockbins adjoining the wharf from which the furnace could be fed. The war broke out while these developments were still in progress, and the company at once complied with the request of the Commonwealth Government to erect a shipbuilding yard for the building of naval and merchant vessels. The expansion already in progress at Whyalla made it an obviously suitable site for the yard and at present it is the largest shipbuilding yard in Australia, with five slipways for the building of merchant vessels up to 12,500 tons deadweight. Further developments followed in rapid succession, including the establishment of a brickmaking plant, a forge shop, an electric steel melting shop and steel foundry, a heavy machine shop and a precision gearcutting shop. Within the last few years the firm of C. A. Parsons Australia, Ltd., has erected a plant for the manufacture of steam condensers and turbo-generators; and a solar evaporation plant has also been established by the Broken Hill Proprietary Company for the production of salt.

The availability of cheap common salt is more or less taken for granted, but it is in fact an essential chemical for the production of soda ash, hydrochloric acid, sodium sulphate and sodium carbonate and bicarbonate for the manufacture of soap, glycerine, glass, dynamite, and many other articles in daily use. To assist in meeting Australia's requirements 500,000 gallons of sea water are pumped daily from the highly saline waters of the Spencer Gulf during a season which lasts throughout the Australian summer, November to April. Processed in the solar evaporation plant, the Gulf waters have already yielded 23,000 tons of salt and the plant is now being extended to produce 30,000 tons a year. The many advantages of Whyalla for solar evaporation include a warm, dry, reliable climate, large areas of almost level land and, above all, the high salt content of the Spencer Gulf water—almost 23 per cent greater than average sea water. Other factors are reliable electricity and fresh water supplies, a deep-water shipping harbour and wharves with bulk handling equipment.

The process begins with the pumping of sea water into the primary evaporation area, from which the brine is pumped to the storage pond, where further evaporation takes place. It is then pumped to the crystallising area, where a brine depth is maintained between 6in and 8in on the salt crust. At this stage the rate at which salt is deposited is artificially increased by almost 25 per cent by the addition of naphthol green dye to the crystalliser brine. This dye is remarkable for its ability to absorb heat radiations at the infra-red end of the solar spectrum, and causes a very perceptible temperature increase in the brine, with increased evaporation. When sufficient salt has been deposited in the crystalliser the brine is allowed to increase in density until all the available salt has crystallised. The residual liquor is drained off quickly to avoid contamination of the salt by excessive deposition of magnesium sulphate. The salt crust remaining is then scarified to full depth with a seven-tined mouldboard plough devised to replace the blade of an auto-patrol grader, loaded direct into lorries by a tracked bucket loading machine, and transported to the stockpile at the blast-furnace wharf. A loading rate of 100 tons per operating hour has been recorded. When being shipped the salt is loaded at the rate of 250 tons an hour, by electric travelling stockbridge, fitted with a 7 cubic yards capacity clam grab.

Expansion of Plant.—The areas of the various units in the plant, as it stood when the initial production process was fully developed, were: for primary sea water evaporation, 74 acres; storage and brine pond, 7½ acres; and crystallising area, 5 acres. When extensions to provide for the projected capacity of 30,000 tons a year have been completed, these areas will then be: for primary sea water evaporation, 470 acres; storage and brine pond, 74 acres; crystallising area, 30 acres. In extending the area a channel 3 miles long has been excavated, and 1600ft of 20in pipe will convey salt water from the channel to the evaporating area. This pipe will be connected to a pump at the blast-furnace wharf. Completion of the first stage, including a new evaporating area consisting of two 5-acre crystallisers, will increase production from 5000 to 15,000 tons a year, and the three further crystallisers to be constructed will bring the plant to its full capacity of 30,000 tons annually. The salt produced at Whyalla has the following approximate composition:—

	Per cent
Insoluble acid	0·10
Iron oxide	0·01
Calcium sulphate	0·68
Magnesium sulphate	0·20
Magnesium chloride	0·26
Common salt	98·40

Most of the salt produced is shipped to the works of the Newcastle Chemical Company, Pty., Ltd., where it is converted to sodium sulphate and ammonium chloride.

MARINE EQUIPMENT EXHIBITION.—An exhibition, which will remain open until March 15, is being held by the Carron Company, which celebrates its bicentenary in two years' time, at its London showrooms, 15, Upper Thames Street, E.C.4. Examples of the variety of ship's equipment manufactured by the company are on view and include small deck fittings, shackles, sidelights and windows, a complete set of cooking equipment, including stainless steel sink units, boiling pans, a calorifier, a baking oven, a steaming oven, coal and oil-fired ranges, an electric range, and a worm-geared electric cargo winch.

African Engineering News

BY OUR SOUTH AFRICAN CORRESPONDENT

Engineering Research Progress in the Union

Slipring Research.—In the use of strain gauges on rotating members, it is necessary to incorporate sliprings of some kind with which the necessary electrical contact between the gauge and stationary measuring apparatus can be maintained. Variations of electrical resistance occur between the moving and stationary parts of the slipring construction, and these are often sufficient to dwarf the small changes in resistance of the gauge when the latter is subjected to small strains.

This problem has caused difficulty in the National Mechanical Engineering Research Institute in attempts to determine the dynamic stresses and vibration characteristics of such machinery as fans and rock drills. It has therefore been decided to conduct research into the transfer of electricity between stationary and moving conductors. An attempt is being made to find a combination of brushes and sliprings, which, under any particular set of conditions, will give resistance changes which are small in comparison with those being measured. In some of the experiments at present in progress silver sliprings are being used with special silver-carbon brushes. In others, solid metal rings rotating in a mercury pool are being tried.

Metallurgical Investigations of Service Failure.—To assist industry the N.M.E.R.I. has established, within its Metallurgy Sub-Division, comprehensive facilities for the metallurgical investigation of service failures, and industry is increasingly availing itself of this service. Typical investigations that have been carried out succesfully relate to failures of the aluminium alloy fan blades of a large gold mine ventilation unit, the impellers of two large centrifugal fans, the shaft of a coal crusher, and a stainless steel pipe elbow. In addition to the normal facilities for microspecimen preparation and polishing, micrography, mechanical testing and heat-treatment, more specialised facilities have also been provided. They include phase-contrast, and polarised-light micrography, surface interferometry and micro-hardness testing.

Heat Exchange between Fluids and Solid Surfaces.—Some fundamental research in heat flow between fluids and solid surfaces is at present being undertaken by the N.M.E.R.I., which has designed a special heater plate for the purpose. A very important and interesting phenomenon arose in the study of heat transfer on vertical plates with forced and natural convection. This is that the film coefficient is greater when the surface of the plate is heated by a flow of air than when the surface is warmer than the air. The reason for this is probably as follows. The flow of a fluid round a body can be caused in two ways, either by forced flow due to a fan or other mechanical means, or by natural currents which arise as a result of differences in density due to temperature gradients. Under normal conditions heat transfer takes place through the combined action of both. But the direction of natural convection will depend on the direction of heat flow, i.e. upwards when the temperature of the plate is higher than the air, and vice versa. If in a given case the forced convection is upwards, the natural convection will flow either with or against the mechanical current. In the latter case, the heat transfer is greater, probably because of increased turbulence.

Research is being undertaken in order to develop a basic theory for this phenomenon, and an attempt will then be made to confirm it experimentally by means of observations using the heat plate.

Research for Railways.—The behaviour of railway tracks under load is being studied by the National Building Research Institute on behalf of the South African Railways. The object of this work is to study sleeper spacing, as sleepers and the associated rail-fixing devices are relatively expensive items. An increase of even a few inches in sleeper spacing could result in a considerable reduction in costs.

Improved facilities for the transport of fish in ice will result from research carried out by the Fishing Industry Research Institute in co-operation with the S.A.R. and the trawling industry. Following these experiments the S.A.R. are preparing specifications for a truck of metal-bodied design specifically for the carriage of fish in ice. Research has shown that trucks for the carriage of fish could be improved in a number of ways. Among these are a reduction in the heavy timber framing which interrupts the continuity of insulation, improved insulation of truck doors, and the replacement of sun shields on truck roofs with thicker roof insulation.

Projected Water Developments in the Union

The suggestion has been made that the surplus water of the Orange River should be diverted into the Great Fish River through a tunnel 50 miles long. The tunnel would be constructed through the mountains dividing the catchment areas of the two rivers ; the Minister of Water Affairs has referred it to the Natural Resources Development Council for investigation.

The main idea of the project is the construction of a tunnel which irrigation engineers estimate would divert for conservation 100,000 acre-feet of water a year—to irrigate 100,000 morgen. The water would be led to the tunnel from a barrage across the Orange River by about 5 miles of canal, starting at the farm Doornpoort, just north of Venterstad. Some of the water leaving the far end of the tunnel would be drawn off by two canals, one going in the direction of Conway and the other towards Hofmeyr. Most of the water would pass down the Theebus spruit into the Great Break River and thence to the existing dam at Grassridge.

Water for the lower Sundays River would be passed down the Great Fish River and would be conveyed by a canal and short tunnel to the Little Fish River, entering it just below Somerset East. The water would be picked up at a suitable point in this valley and would be taken to the head of Schoenmaker's spruit. The bulk of the flow would then pass down the spruit into Lake Ulentz for storage.

New water supply projects for the Orange Free state, more particularly for its drought-stricken areas, are under serious consideration. In addition the expanding goldfield areas have to be provided for. The suggestion, therefore, that the Madibamitso River, in Northern Basutoland, could be dammed would appear to deserve close attention, especially if such a scheme would make the Free State largely independent of other sources of supply. This project, including a hydro-electric scheme capable of developing 350,000MW per annum, is being investigated.

Two other schemes with the same object are under consideration. One of these concerns the Semana River and the other is what is known as the Ox Bow Lake project.

New Dam for Kariega River.—The Cape Provincial Administration has approved in principle the contemplated Kariega River water augmentation scheme, which, when completed, will mean an 880-million-gallon dam to serve Grahamstown and district. Work on the new dam will be begun within the next twelve months. The dam will take about two to three years to construct. The area is well below the confluence of the Kariega and Palmiet Rivers and will have the full benefit of the Kariega River catchment area as well as the overflow from Howieson's Poort, which is on the Palmiet River.

Slag and Masonry Cement

Blast-furnace slag is generally regarded as a waste material and is thrown on the large dumps found in the neighbourhood of steel works. If, however, the slag, on being drawn from the furnace in a molten state, is chilled rapidly with jets of water, a process known as granulation, it yields a product similar in appearance to coarse sand. If this granulated slag is then finely ground with a suitable activator, such as lime, cement clinker or gypsum, a material which in many ways resembles Portland cement in its properties is obtained. Cements made in this way have long been used in Europe, but there was some doubt whether a satisfactory product could be made from South African blast-furnace slags on account of the higher magnesia content which results from the use of dolomites as a flux in the furnaces.

Working in co-operation with the Iron and Steel Corporation, Ltd. (Iscor), in Pretoria, the National Building Research Institute was able to demonstrate that, despite the high magnesia content, an excellent blast-furnace slag cement could be made from Iscor slags. As the potential production of slag cement from this source amounts to about 500,000 tons per annum, or roughly 13 per cent of the existing production of Portland cement in the Union, this research has provided the means for a substantial increase in the Union's cement production.

Slag cement is now being marketed to an increasing extent, not only by Portland cement manufacturers, in the form of Portland blast-furnace cement, but also by a new firm producing only blast-furnace products. Plant for granulating slag is being installed on a commercial scale at both the Pretoria and Vanderbyl Park works of Iscor.

More recently the N.B.R.I. has undertaken further research with the aim of producing masonry cements from blast-furnace slags. Cements of this kind, unlike Portland cement and ordinary slag cement, are not suitable for structural concrete, but are finding increasing application overseas in mortars and plasters. Satisfactory results, which have been obtained from development work undertaken by the N.B.R.I. and sponsored by a newly-formed company, together with work done by this firm in its own laboratories, have led to the manufacture of a masonry cement by the firm concerned.

Open Pit Working Contracts for Nchanga

The conveying equipment contract for what is the largest earth-moving project yet tackled in Africa is to be supplied by Robins Conveyors and Jeffrey-Galion. More than 90 per cent of the plant will be fabricated in the Union largely from South African raw materials. Two integrated systems of conveyors will be provided, which are planned to extend more than 2 miles from the open pit workings at Nchanga to a huge waste dump in the bush. Two bucket wheel excavators are to be arranged to cut continuously " benches " or steps at 86ft intervals through the soils and clays overlying the ore-body, and the conveyor system will run the waste to the dump at a rate which will be built up to about 50,000 cubic yards a day. The conveyor systems will be divided into three interlinked sections. Two 5000ft units, 42in wide, will be sufficiently portable to follow the bucket wheels into various parts of the pit, which may ultimately be 600ft deep and 4000ft wide. These two sections will discharge the soil on to elevating conveyors, which will carry the load to the surface, where a 54in wide conveyor belt takes over, bringing the soil to the dump at a speed of 800ft per minute—about 9 miles an hour. The third 4000ft conveyor section, which will also be portable, will take the soil to a mechanical stacker, a machine that spreads the waste suitably over the dump area. The plant, which is to be powered by electric motors of about 4500 h.p., is due to be completed by December, 1957.

Kariba and the Zambesi

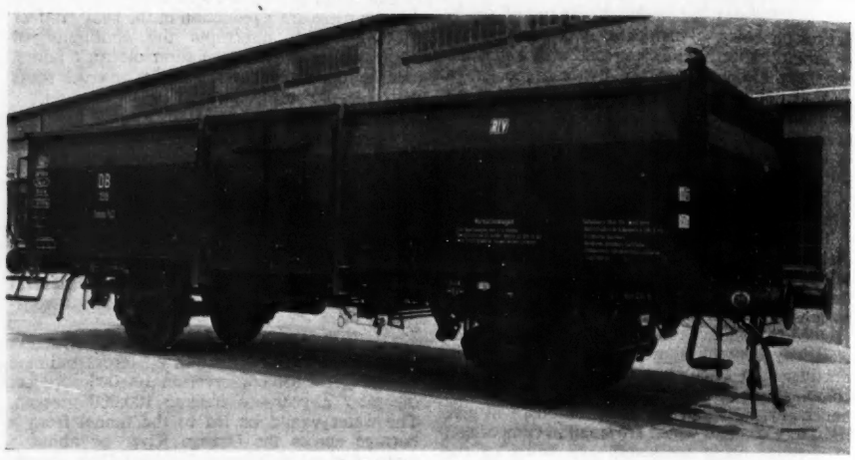
Since September, after the Zambesi had fallen to its critical height of 1265ft above sea level, there has been a new sense of anticipation of things to come at Kariba. The north bank cofferdam foundations, laid last year, have been exposed, and the retaining wall is rising rapidly. Within this temporary wall the first section of the main dam will be built.

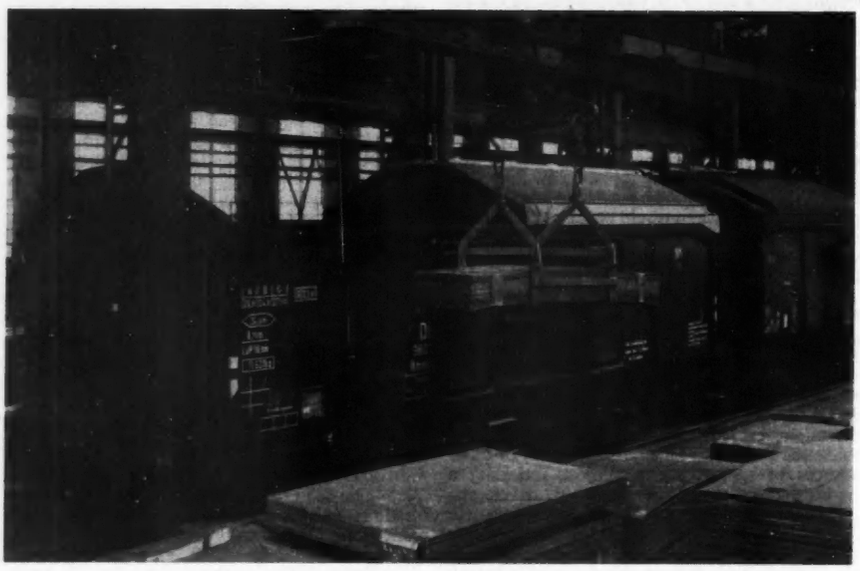
The steelwork is in place on the road bridge across the Zambesi. The Italian company, Impresit, has ordered another bridge to span the Sanyati, which joins the Zambesi 2 miles above the dam site. Gravel is to be excavated in this area. The diversion tunnel has been broken out at both ends, portals are being constructed and the last of the rock has now been blasted.

The design of the power station has been discussed by the joint consulting civil engineers at meetings in London and Paris. Various alternative plans have been drawn up and contractors on site have been asked to speed up excavation work so that samples of the rock conditions encountered may be studied. On their findings in the heart of the hillside depends the design to be adopted.

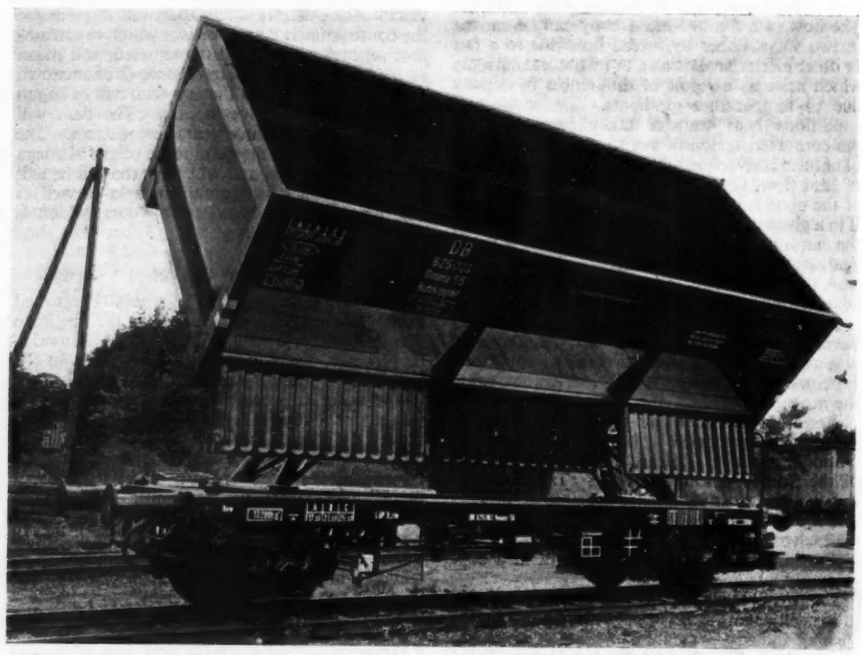
GERMAN GOODS WAGONS

On its 30,500km of route, the Deutsche Bundesbahn (German Federal Railway) operates nearly 280,000 freight cars. Not counting privately owned rolling stock, the Federal Railway last year effected approximately 19·6 million freight car journeys, an increase of 3·5 per cent over 1955. In order to cope with the increasing traffic successfully, and without using additional manpower—in some districts there has even been a loss of labour to other industries—the German railway administration is carrying out a programme of reorganisation and mechanisation of the goods handling facilities. Great efforts are being made to modernise obsolete rolling stock and to replace worn-out freight cars by new ones. Between January 1 to October 20, 1956, the railway took delivery of 11,475 goods wagons. During the same period, some 4500 old wagons were taken out of service, so that there was a net increase last year amounting to about 7000, compared with only 1500 the year before.





Much of the increased efficiency in the goods yards is due to the greater employment of machinery. Pallets and fork lift trucks are used in the majority of depots, and in many instances the whole of the work is carried out by these means. Much of the out-of-date rolling stock is given a new lease of life by complete overhauling and rebuilding. An increase of productivity is also sought through the introduction of improved versions of standard wagons and the more widespread application of special purpose designs. In the accompanying illustrations we show some of the cars which have been developed. The wagons are of welded construction and—like 81·4 per cent of the German freight cars—are equipped with air brakes (the remaining 18·6 per cent are fitted with air brake piping only). The open wagon "Omm 52" (top, right) has a length over buffers of 10m, a maximum width of 3·044m, and a height above the rails of 2·74m. The loading space measures 8·76m by 2·76m by 1·50m high. With a useful floor area of 24·1 square metres, it has a volume of 36·3 cubic metres, and can carry 30 tons for a tare weight of 9·8 tons. The second illustration (left) shows the "Kmmks 51" covered wagon with sliding roof. Overall length is 10m, maximum width 2·98m, and the height above the rails is 4m. The car has a loading space of 8·76m by 2·76m by 1·68m, a useful floor area of 24 square metres and a volume of 49 cubic metres. The loading capacity is 28·2 tons, and the tare weight, 11·3 tons. Below, there is shown a recent tipping wagon, the "Ommu 56." This version has a container holding up to 25·5 tons which can be raised bodily before it is tipped, thus enabling material to be transferred directly to lorries. Overall length is 9·2m, with a wheelbase of 58m, width 2·76m, height 1·72m, and tare weight, 13 tons



All-Wheel-Drive Diesel Truck

The German Ford Motor Company, of Cologne, has recently put on the market an all-wheel-driven 4·5-ton vehicle, which, available as a truck or as a tipper, has been designed particularly for the requirements of building contractors (Fig. 1). Like the standard 4·5-ton rear-wheel-drive lorry of the same firm, the new vehicle is powered by a six-cylinder, 4·2-litre, two-stroke diesel engine developing 120 h.p. at 2800 r.p.m. The engine, previously described in our report on the Frankfurt Motor Show of October 21, 1955, has six loop-scavenged cylinders in 90 deg. vee arrangement, and a gear-driven Roots blower between the two cylinder banks. The torque is transmitted through a four-speed and reverse synchronised gearbox and an open propeller shaft to a transfer box which also incorporates an auxiliary two-speed gear with the low ratio of 1·9 : 1 ; the engagement of gear is effected by dog clutches (Fig. 2). From the transfer box two propeller shafts lead, respectively, to the front and to the rear axle. Both have hypoid final drive gears with a reduction ratio of 7·166 : 1. In other respects the vehicle is quite orthodox. The chassis, together with driver's cab, weighs 3·1 tons. Air pressure-assisted, hydraulic brakes are fitted.

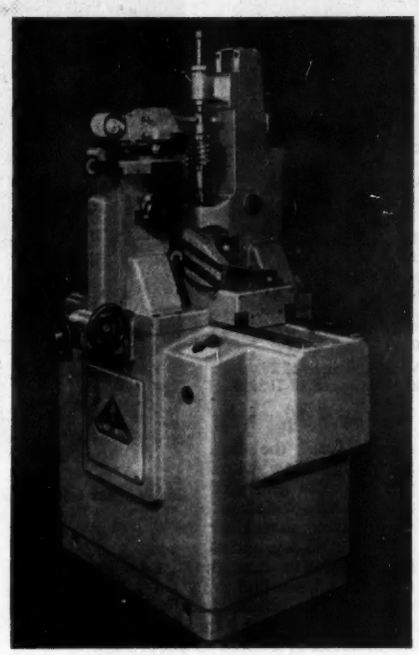
Like most other types of all-wheel-driven vehicles the new Ford model relies for normal driving upon the rear-wheel drive ; the front-wheel drive is used only when the grip of the rear wheels is insufficient to provide the required tractive effort. While usually it is left to the driver to decide when to use the all-wheel drive, the Ford vehicle is fitted with a freewheel deivce which engages and disengages the front-wheel drive automatically according to the road conditions, in direct response to the prevailing rolling resistance. This device consists of a ratchet free-wheel located inside the transfer box between the gear train and the output to the front propeller shaft. The gearwheel *A* at the intake end of the drive shaft has one tooth more than wheel *B* on the drive shaft leading to the rear propeller shaft. As long as the front wheels, pushed by the rear wheels, are running at the same speed as the latter, the front-wheel propeller shaft overruns the gearwheel *A*. If, on the other hand, the tractive effort is too great for the rear axle, then the rear drive shaft overruns the front-wheel drive shaft and automatically engages the front-wheel drive. Under ordinary road conditions the rear-wheel drive is generally sufficient to meet most operational requirements ; the necessity for engaging the additional front-wheel drive rarely occurs and then only for comparatively short periods. In order to maintain the automatic operation of the front-wheel drive also when reversing, a second freewheel device (not shown in our illustration) is provided which is pneumatically engaged when the reverse gear of the main box is selected.

Automatic operation of the front-wheel drive is stated to improve the handling properties of an all-wheel-drive vehicle, and to obviate the indiscriminate application of the auxiliary front-wheel drive, which is not only wasteful with regard to fuel consumption, but also causes excessive tyre wear and undesirable stresses in the transmission lines.

Hob Testing Machine

A particular source of inaccurate gear profiles is the transfer of hob sharpening errors to the gears in the cutting process. In the manufacture of precision gearing, inspection of the hobs used is therefore of great importance.

Our illustration shows a hob tester, the " Model PWF 250," made by W. Ferd. Klingelnberg Soehne, Remscheid, German Federal Republic. The machine comprises a base for carrying the longitudinally travelling rolling slide, a vertical column with work drive and another column which carries the gauging head and the electronic stylus unit.



Tester for hobs of 2½in to 10in diameter, and 1½ to 10 D.P.

The hob is mounted between the centres of the workhead and driven by means of a special true-running driver. The drive is taken through two rolling discs, mounted on a common axis, against which is held a guide bar fitted to the rolling slide, causing the longitudinal travel of the slide to be converted into a rotary motion of the rolling discs and workpiece without any sliding losses.

A horizontally swivel-mounted guide, which can be set at the required angle, permits movement of the measuring slide in parallel with the axis of the hob. The stylus unit is mounted on the measuring slide and is adjustable.

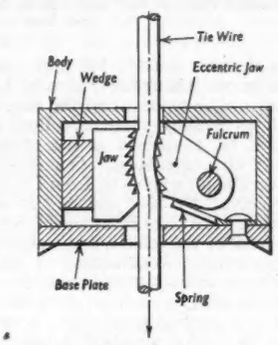
Tests can be carried out for accuracy of lead, gash spacing and flank profile ; checking the flute spacing and flute lead ; true running over tooth crests ; absence of face profile errors ; concentricity and axial slip of the test register ; and thread spacing on multi-start hobs.

The distance between workhead centres is adjustable up to 18½in, and the machine can accept hobs from 2½in to 10in diameter, with a diametral pitch of 1¼ to 10. Maximum base lead angle is 40 deg., maximum base circle diameter 3½in, and the maximum height of the lead measured 6½in. The test piece can make up to six complete revolutions at speeds steplessly variable from 1 to 7 r.p.m., or can be driven by hand. Measurements are automatically recorded on a chart with a magnification of up to 500. No index plate is required for rotating the hob.

British agent for this machine is Sykes Machine Tool Company, Ltd., Hythe End House, The Hythe, Staines, Middlesex.

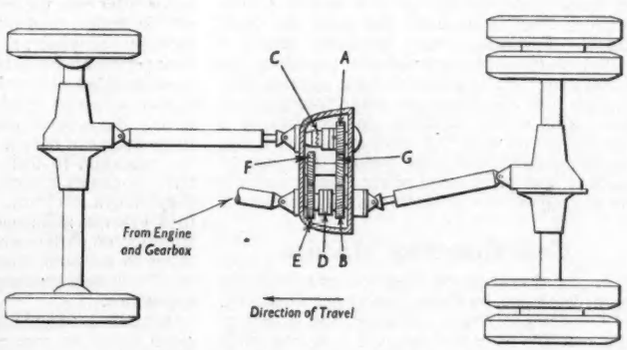
Steel Lock for Tie Wires

We have received details of a locking device for tie wires used in shuttering, made by Cuno Schückhaus K.G., Düsseldorf-Benrath, Urdenbacher Allee 57, German Federal Republic. The " Steel Lock " is stated to grip the wire in an absolutely reliable fashion not only while the latter is under tension but also under compression, as may happen when vibrators are used to consolidate the concrete. The device is made entirely of steel, and its operation may be understood by reference to the accompanying sectional view. After the wire has been threaded through the lock and suitably tensioned by means of a lever (which the maker also supplies), the wedge is driven home and the wire is gripped between the curved serrated jaws. Under the wire tension, the rotatable eccentric jaw tends to increase its grip. When the wedge is withdrawn, the spring returns the jaw to its " open " position, and the wire is released. The two standard versions of the lock accommodate wires of 2mm to 8mm or 3mm to 9mm diameter.



Steel lock for tie wires

Fig. 1—4·5-ton Ford four-wheel-drive diesel truck



A—Front transmission gear with one more tooth than gear *B*.
B—Rear transmission gear.
C—Freewheel.
D—Dog clutch which engages either *B* or the auxiliary reduction gear train *E-F*.
G—Intermediate gear.

Fig. 2—Diagrammatic view of all-wheel-drive, showing transfer box

Producer Gas Plant for Cars and Tractors

During the last war, every car, lorry and tractor in Sweden was driven by a producer gas plant using wood and charcoal. In 1950, the development of such plant was taken up again by Aktiebolaget Volvo, of Göteborg, and has now resulted in designs suitable for mass production should the petrol situation require it. Lorries and tractors use chopped wood for fuel, while passenger cars employ charcoal. Both kinds of plant will be assembled at the company's main factory at Gothenburg. Our illustration shows the version for engines of from 1 to 2 litres such as the Volvo " PV-444 " and the " Amazon " passenger cars. The plant is designed for mounting in the front of the vehicle, and weighs 75 kg complete with fuel. Roadholding or handling are not affected and all the components of the equipment get efficient cooling. It takes about five minutes to start up from cold ; re-starting after 1 to 1½ hours' standstill takes two to three minutes. While efficiency is only about half of what can be achieved with petrol, and acceleration is poor, the power is stated to be sufficient to maintain quite a high average speed on the road, once the driver has got used to the technique of driving with a producer gas plant. For cars for which this size of plant is intended, 100 litres of charcoal 20mm to 40mm in size will last for 120km to 150km, with top speeds of 100km to 105km per hour.

Producer gas plant for cars with engines of 1 to 2 litres. About 100 litres of 20mm to 40mm diameter charcoal lasts up to 120km to 150km at a top speed of 105km per hour

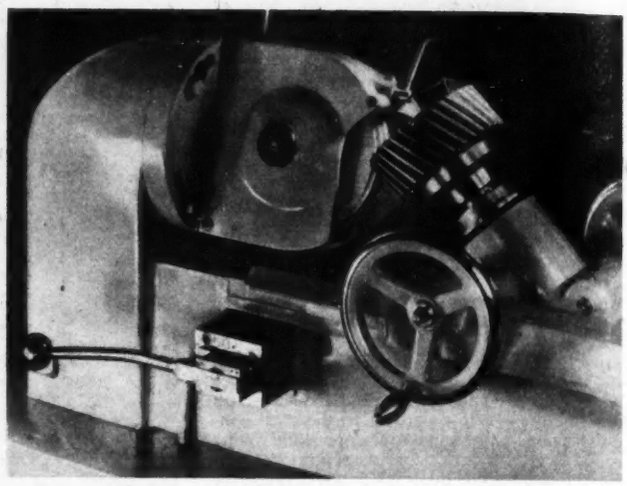
For lorries and tractors the plant consists of three units : the generator which is mounted on the left side of the chassis, the cyclones on the right, and the final cooling and cleaning unit mounted at the front. The equipment is made in three sizes for lorries and two sizes for tractors, and is basically the same for both classes of vehicle. Very successful tests are stated to have been carried out regarding the use of diesel oil and producer gas in combination, in a ratio of about one part oil to four parts of gas. This system obviates the necessity of a costly conversion of the diesel engine, including its being fitted with iron pistons and electric ignition, and gives more power ; plant suitable for engines of 3·5 to 10 litres has been developed.

Gear Deburring Machine

A new deburring machine for gear teeth has been developed by Gebr. Boehringer G.m.b.H., of Goeppingen/Württ, Germany, and details of this machine have been received from the firm's British Agents, the Sykes Machine Tool Company, Ltd., Staines, Middlesex. The machine is designed to remove burrs from spur and helical gears from 5 to 51 D.P. and up to 15¾in pitch circle diameter.

The machine can be seen in operation deburring a helical gear in the accompanying illustration. In the wheelhead an 8in diameter grinding wheel is driven at 2800 r.p.m. by a 1 h.p. motor and its periphery has a worm profile, corresponding to the tooth form and pitch of the workpiece, a separate grinding wheel being required for each individual tooth form. The head can be set at angles up to 25 deg. each side of the centre-line in order to match helical gear angles.

The gear wheel to be deburred is mounted on a freely rotating arbor and derives its rotational motion from the lead of the grinding wheel profile. The gear and the grinding wheel are so engaged that their axes are at 45 deg. and as both revolve in mesh the tips, flanks and roots of the teeth are uniformly deburred. Grinding wheels for use on the machine are profiled on a separate machine or lathe and can be used until the diameter is reduced to about 5½in.



Helical gear being deburred on machine which handles spur, helical and bevel gear with a maximum pitch circle diameter of 15¾in

Automatic Air Filter

A self-cleaning filter for removing atmospheric dust from ventilation air has been developed by A.B. Svenska Fläktfabriken, Stockholm. The filter is of the viscous impingement type with rotating filter screens, and is stated to combine a high collecting efficiency with low air resistance and small dimensions.

The factors which enter into the practical application of an air filter are the collecting efficiency, air resistance, and dust accumulating capacity. For expressing the efficiency of a filter it is usual to use one of two methods. The efficiency may be expressed as the proportion by weight of the dust in the airstream which is collected by the filter, or one may use the " blackness efficiency " (National Bureau of Standards). In the latter case, the test is carried out by drawing off air before and after filtration, passing it through filter paper, and adjusting the flow until both papers are being blackened at the same rate, as determined photo-electrically. The efficiency is then taken as 1 minus the ratio of the two flows. Since small particles which are difficult to separate out have a greater blackening power in proportion to their weight than larger ones, the " blackness efficiency " is usually lower than the " weight efficiency." Actual figures obtained in a given case depend, of course, on the distribution of particle sizes in the dust, so that in order to get comparable data, different designs of filter should be compared under the same test conditions.

Air resistance and efficiency are related for any given design as greater collecting efficiency can always be obtained by decreasing the openings of the filter layer, thereby increasing also the resistance, and vice versa.

Dust collecting capacity should be as high as possible, otherwise increased maintenance and operating costs would result. A large capacity should not, however, entail a low filtration efficiency or too great a resistance.

For the present design, the model " LFP6," it is claimed that its air resistance and efficiency are virtually constant, and that its maintenance costs are low as it is self-cleaning and automatic. The filter has oiled impingement surfaces which bind and retain the dust which is present in the air passing through. The arrangement consists of two endless moving screens, the first being the filter screen and the second an oil-drop eliminator. These screens are supported at the top by horizontal shafts provided with longitudinal slats. The driving mechanism is at the top and incorporates a ratchet gear which, at each stroke, moves the portion facing the airstream 80mm down and 75mm up. The oil-drop eliminator moves in the same fashion, but at half the speed in order to give lighter oiling, and here it is the downstream section which moves downwards. In order to obtain the best rate of feed with regard to dust accumulation and the maintenance of the correct oil films, the screens are driven intermittently by means of a time relay ; total running time is about 30 minutes per day.

The screens run between sealing strips fitted to the side walls of the filter and dip into an oil bath at the bottom. They are weighted down by means of shafts similar to the supporting shafts, but not running in bearings. When the screens rotate the longitudinal slats on the shafts act as simple pumps and force oil through the screens, thus contributing to efficient self-cleaning. The dust washed out collects at the bottom of the oil bath and is periodically raked out.

Eleventh Sectional Meeting of World Power Conference

THE Eleventh Sectional Meeting of the World Power Conference will be held in Belgrade from June 5 to 11, 1957. The main theme is " Power as a Factor of Development of Under-developed Countries." The technical programme is in two main divisions, and is available in English, French, German and Russian. Technical sessions will be held for the discussion of the papers submitted (which will not be read) and visits will take place to power plants and industrial enterprises in Belgrade and its neighbourhood. A number of social events are also being arranged, as well as post-conference tours to various hydro-electric plants, thermal plants and industrial establishments in Yugoslavia. The itinerary has been chosen so as to provide for visits to places of historical interest and to give participants the opportunity of seeing some of Yugoslavia's beautiful scenery. Details may be obtained from the British National Committee of the World Power Conference, 201–202, Grand Buildings, Trafalgar Square, London, W.C.2.

Surface Leakage Problems on High-Voltage Insulators

We reprint here abstracts from a paper by A. D. Lantz, Jr., development engineer of the Ohio Brass Company, Mansfield, Ohio. This paper was presented last autumn at the ninth annual Power Distribution Conference of the Department of Electrical Engineering, University of Texas. The author reviews problems of insulator surface leakage, contamination and cleaning methods. He refers to protective measures, including the use of silicone compounds for coating the insulator surface.

SURFACE contamination and surface leakage currents caused operating difficulties in the infancy of electrical power transmission, some eighty years ago. Since that time, other operating problems have been recognised and solved. Surface leakage currents, however, have demonstrated amazing resistance to well-organised attack and exist to-day as one of the few remaining insulator service problems. Surface leakage currents can be responsible for serious operating problems such as line outages, abnormal corrosion of energised metal parts, and burning of wood structures. All of these difficulties affect service continuity, utility customer relations, and have an objectionable influence on operating expense. Increasing industrial activity has aggravated this problem, particularly since World War II.

After the appearance of operating problems caused by surface leakage currents, various special insulator designs appeared. Some of these included oil reservoirs to interrupt the leakage path, heaters to prevent moistening of the insulator surface, labyrinth enclosures to retard the accumulation of dirt and the entrance of moisture and designs with shapes supposed to facilitate the natural cleaning action of rain. The degree of success of most of these unusual designs was evidently not outstanding since most have disappeared from current practice.

Undoubtedly, some of the early tests and early experience were handicapped by lack of understanding of the fundamental nature of leakage current. On many occasions, a user arbitrarily substituted a new style of insulator for no sound reason other than that it had an appearance different from an existing one which failed to solve a leakage current problem. Such designs frequently operated satisfactorily for an initial period of time because they were clean and the victim then optimistically concluded that the change in performance was due to the changed design. When the replacement inevitably became contaminated and troublesome, the original rash conclusion nevertheless remained. Unfortunately, the selection of the best insulator to operate in any given atmosphere generally requires several years' experience plus a well-organised evaluation programme.

Early laboratory studies were bent largely on a quest for the perfect contour. Here, again, lack of understanding of basic phenomena robbed these efforts of any logical approach. Quite elaborate dusting-fogging chambers were built so that insulators could become contaminated and tested for flashover voltage, damp surface resistance, or ability to hold voltage for a particular time interval. Much effort was put into the reproduction of specific contaminants or the search for a universal contaminant, a pursuit periodically resurrected.

The lack of specific knowledge about surface leakage plus the inherent variabilities of fogging, dusting, compounding and testing justified almost any desired conclusion regarding insulator shape or the effect of such things as leakage distance, sheltered or exposed leakage distance, and other factors. It is, therefore, not surprising that the market was flooded with insulator designs of high confusion value, but no other long-term merit.

Recognition of Leakage Current Characteristics

When voltage is applied to an insulator, three separate and distinct currents may flow between the energised electrode and ground. The first (and least) of these is conduction through the dielectric, an amount measured in micro-micro-amperes. The second current, measured in micro-amperes, leads the applied voltage by 90 deg. and is the charging current through the insulator capacitance. The two currents above are never troublesome and are not altered by surface conditions. The third current, which is the subject of this paper, is conducted through deposits on the insulator surface and is in phase with the applied voltage.

About twenty-five years ago, basic studies of surface leakage current characteristics were undertaken by several different investigators. It was found that leakage currents flowing over contaminated surfaces are generally of a low order of magnitude, on the order of 5mA to 10mA or less base current. Randomly dispersed along this current base are intermittent surges of a few cycles duration with current peaks as high as 100mA to 200mA r.m.s. These conditions may exist for periods ranging from a half-cycle to several minutes.

The surge-like nature of leakage current is caused primarily by the non-uniformity of the surface moisture film. Contaminated dry insulators are generally trouble-free. Contaminated wet insulators are not uniformly conducting over the leakage surface. When one area of the insulator develops a thinner, high-resistance film, a disproportionate share of the instantaneous applied voltage appears across this area. If the voltage that appears is sufficiently great, sparking occurs and an arc develops across what was formerly a voltage carrying surface and the current increases, limited only by the resistance of the remaining "unshorted" film. The arc tends to move along this film toward the insulator terminals, increasing the current level as the remaining resistance is diminished. A main stabilising factor is the increasing current level required to maintain the progressively longer arc. As a second stabilising factor, the high instantaneous power associated with the current surge thins out the remaining "unshorted" film. The increased resistance of the thinner film reduces the current and tends to quench the main arc, returning the leakage to a low-level, harmless "spitting" condition. If the original partially "shorted" film has relatively high conductivity, the current will be high enough to sustain long arcs and a full flashover may result. Occasionally, this sequence of events will occur in a few cycles and develop a full flashover over an insulator showing no apparent distress. An approaching flashover might be indicated either by surges of increasing magnitude or decreasing interval.

A rough approximation of surface leakage current magnitude can be made by visual observation of surface distress. If the surface activity consists of blue sparks accompanied by a "crackling" sound, the current level is probably below 2mA and does not indicate flashover imminence. If the surface arcs are thick and yellow, accompanied by a "hissing" sound, the current probably exceeds 25mA and indicates a condition that may lead to flashover.

Recordings of field leakage currents and laboratory tests indicate that flashover of an insulating member is imminent when surges reach a value on the order of 100mA. Under the majority of conditions typical leakage currents would be on the 2mA to 10mA range. It is known, however, that relatively uniform low-resistance surface coatings may safely carry steady state leakage currents of the 100mA to 150mA level. Such a condition is temporary since the power loss of several kilowatts on a typical high-voltage insulator hastens drying and the character of the leakage current soon reverts to the low base level, high intermittent surge condition.

A low level current of 5mA or less will initiate pole fires in the event that the pole construction details, moisture content of the wood, and other factors are right.

The non-uniformity of coating applies to the total leakage path whether over a single insulator or several insulators of a long string.

In a laboratory wet flashover test (at a voltage of about 70kV) on a naturally contaminated three-unit insulator string, the flashover current is limited by external impedance to a value which can be carried by the top surfaces of the individual insulator units. The good insulating portions of the insulators are shorted by external arcs while the top surfaces are conducting the full current without external arcing. At a voltage of 40kV to ground, no arcing was visible and the string operated three years outdoors with no significant surface leakage.

Direction of Present Studies

As a result of a better understanding of the basic characteristics of leakage current, most researchers have discouraged indoor laboratory approaches. The standard laboratory wet flashover test on new-clean insulators is not necessarily indicative of performance under leakage conditions. Service performance cannot be accurately evaluated other than by actual operation under the precise conditions of moisture, and type and amount of deposit that prevail at the service location. Two types of service installations are under study by the Ohio Brass Company.

In the outdoor test installation at the high voltage laboratory in Barberton, insulator specimens of various sizes and shapes are exposed to industrial and road dust contamination while energised at normal or slightly above normal line voltage, 44kV to ground. Each insulator is in series with an isolating unit so that currents flowing over the specimen are conducted into the laboratory building and recorded on individual surge counting units. The counter consists of a rectifier type sensitive relay set to respond at a preselected level. Leakage current over insulator passes through a sensitive a.c. relay. The operating current of the relay is set by shunt resistance. Each operation of the relay registers one count on a 110V counter. A neon lamp protects the relay from overload currents. Several identical circuits can be connected in series with relays set at

different operating currents in order to classify surges according to amplitude.

Generally, the counters are adjusted to record surges exceeding 50mA r.m.s. and will respond to the first half cycle of surge. Voltage is maintained through foul weather by an automatic reclosing system. This test installation has permitted a quantitative evaluation of the effects of different insulator shapes, the effect of over-all leakage distance, the value of protective surface coatings and other factors.

In a complete service installation at a 138kV to 23kV substation, selected insulators are connected to ground through multi-stage counter units which record the leakage surges exceeding different levels during foul weather. The counters for this installation record the number of surges exceeding current levels of 10mA, 50mA, and 100mA. During the five-year life of this installation, the substation has experienced four foul weather flashovers. At the time of each flashover in the substation, the specimen insulator carried leakage currents exceeding 100mA. Conversely, there have been no 100mA surges on occasions when flashover did not occur. While the number of counters installed in this station is small, the 100 per cent correlation at the 100mA level confirms the general conclusion that flashover is imminent when surges reach the 100mA level. A larger sample size (number of counters installed) would be expected to give increased reliability of indication of approaching trouble, at a time when counter-measures could be effective. Pronounced leakage current activity requires immediate cleaning, if flashovers are to be prevented.

Effectiveness of Cleaning Methods

While practised to some degree prior to 1920, high-pressure hot-line washing did not become widely used until after World War II. This procedure is now standard for many companies operating in areas of wide-spread contamination and washing may be done as a routine operation at definitely established intervals or it may depend on signs of approaching trouble. Where the contamination may consist of predominantly soluble materials with no binder, hot-line washing removes most of the foreign material.

More commonly, soluble or conducting materials are held in a sponge-like matrix formed of hard industrial deposits or other inert material, including soil dust. In such a case, hot-line washing will not restore the full insulating value of the insulator and it is necessary to make provision for hand cleaning when the deposit has reached a point where hot-line washing does not give sufficient relief. A recording-milliammeter strip chart of the leakage currents flowing over a four-high stack of switch insulators units during hot-line washing in a 138kV substation shows that the current during the initial washing pass reaches a value of about 40mA and reaches a crest value of about 25mA to 30mA during succeeding passes. If the insulator were completely clean, this value would not exceed about 10mA, based on the resistivity of the water used during the washing in this specific case. This insulator stack is located in a substation about 200 yards from a coke oven so the deposit is a relatively tenacious build-up of organic materials.

Hand cleaning with damp or dry cloths does not seem to be much more effective in removing deposit films than does hot-line washing. This generalisation should be tempered by the nature of specific deposits but it seems to apply to contaminations which include a film of soil, organic materials, or other compounds which form an adherent film. Some of these films respond well to paste soap mixtures which include some abrasive, and one of these soaps tried in the Barberton Laboratory restored full insulating value (as measured by wet flashover) to a series of contaminated insulators.

Certain types of foreign material respond well to chemical dips ; for instance, cement dust deposits are softened readily by short dips in solutions of ammonium bifluoride or hydrochloric acid. Hydrochloric acid has been applied to insulators in service although the over-all cleaning expense is probably not much less than the cost of insulator, change-out and cleaning on the ground.

Recent interest has been shown in a portable abrasive blast machine suitable for hot-line cleaning. This machine restores full insulating value to an insulator in service. The cleaning time is said to be three to four times that of hot-line washing but the over-all expense is less than insulator removal or hand cleaning on de-energised circuits. If improperly selected, the abrasive material may roughen the porcelain glaze and hasten the collection of dirt. Also, if improperly directed, the abrasive can remove some of the protective galvanising on metal parts adjacent to or included in insulator assemblies. Abrasive blast cleaning fills the gap between hot-line washing and complete manual cleaning. For certain types of deposits, particularly those that have hard films, a satisfactory cleaning routine might well consist of frequent hot-line washings plus occasional abrasive blast cleanings.

Protective Measures

Protective coatings of one sort or other have been used for many years to aid in the removal of contaminants, primarily by preventing the tight bond between hard films and the insulator surface. They include petroleum waxes, asphalt paints, and other materials which are readily dissolved by organic solvents or which respond well to mechanical cleaning. Some of these are still popular with many companies.

In recent years, silicone compounds have been suggested at various times as an aid in preventing the accumulation of dirt. This is due to an extreme smoothness of the silicone coat and its non-adhesive tendencies. Silicones recommended for this purpose have generally been of varnish consistency so operating life has not been outstanding. Additionally, the expected reduced rate of dirt accumulation has generally not materialised, at least on energised outdoor exposed insulators. During the autumn of 1953, the interest in silicone compounds increased and samples of different coatings were placed on insulators on test in the Barberton outdoor test rack. By accident, a sample of silicone wax was found and insulators were coated with this material and placed on test. The results of the wax coating were so outstanding that additional samples were placed on test the following year. As of this date, sixteen silicone compounds have been tested and the results of wax or paste compounds have been outstanding. Some of the thin fluids have demonstrated an apparent effect for periods as long as one year. None of the silicone waxes has given less than perfect performance on the leakage current test for the full test time.

The test rack, as explained earlier, records the quantity of surges exceeding 50mA. It is felt that surges below this level are in no danger of initiating flashover. The accompanying table summarises the pertinent factors about the performance of the silicone coatings. Coatings A, B, and C are silicone compounds No. DC-5, No. DC-4, and No. DC-44, products of the Dow Corning Corporation. Coating D, also showing perfect performance in Barberton, was factory applied by Process Equipment Industries, Inc.

Leakage Current Study of Surface Coatings on Three Unit Strings of 5¾in by 10in Suspension Insulators : Surges Exceeding 50mA

Coating code letter	Coating description	Coating application method	Total test time to Sept. 1, 1956, months	Test time prior to first surging months	Quantity of surges during first six months	Quantity of surges during first year	Quantity of surges during second year	Quantity of surges for total test time
A	Silicone wax	Hand-cloth	24	—	—	—	—	0
B	Silicone wax	Hand-cloth	24	—	—	—	—	0
C	Silicone wax	Hand-cloth	24	—	—	—	—	0
D	Hard wax	Factory	24	—	—	—	—	0
E	Thin silicone fluid	Spray, brush, dip	24	15	—	—	48	48
F	Thin silicone fluid	Spray, brush, dip	24	7	—	2	49	51
G	Thin silicone fluid	Spray, brush, dip	24	5	5	9	79	88
H	Thick silicone fluid	Brush, hand-cloth	24	15	—	—	75	75
J	Thin silicone fluid	Spray, brush, dip	24	5	5	35	43	78
K	Corrosion inhibiting grease	Hand-cloth	24	15	—	—	15	15
L	Wax solution	Dip-elevated temp.	24	14	—	—	90	90
M	Asphalt solution	Spray, brush, dip	24	5	6	38	40	78
N	None	—	24	5	12	31	48	79
O	White glaze	—	24	5	14	20	49	69
P	Hard film	Factory	21	13	—	—	120	120
A_1	Silicone wax	Hand-cloth	34	—	—	—	—	0
E_1	Thin silicone fluid	Spray, brush, dip	34	7	—	21	9	56
F_1	Thin silicone fluid	Spray, brush, dip	34	2	198	198	62	309
N_1	None	—	34	2	122	122	14	173
Q	Thin silicone fluid	Spray, brush, dip	34	2	32	35	19	103
R	Silicone emulsion	Factory	34	5	62	62	—	62

Following the success of the silicone waxes, greases of other types were placed on test but none of these has been exposed for periods long enough to yield positive information. Other surfaces on test include such plastic materials as fibreglass reinforced resin, "Teflon," polyethylene, and three varieties of strippable plastic coatings. It is expected that the latter coatings will simplify the removal of heavy collections of dirt.

The exact mechanism of the silicone protection is not clear but it appears that the coating insulates each dirt particle and thus prevents the build-up of continuous conducting paths between terminals. Additionally, the water repellent features of the silicone coating may keep the surface dry when water might otherwise condense. The mechanism of protection may be clarified by results of non-silicone grease coatings.

One feature of silicone coatings should be mentioned. The effective coatings have tacky surfaces and accelerate initial dirt collection. This was an alarming observation during the early phases of the test programme. But it was found that the dirt was harmless.

It would be too much to expect silicone coatings to yield leakage current relief for heavy deposits although the presence of such a coating should prevent any bonding action between the contamination and the insulator surface and thus facilitate the recovery of new insulating values. Additionally, silicone coatings may not have beneficial effect on abundant quantities of conducting materials such as might accumulate on sea coast applications. Unquestionably, the heavy

silicones are beneficial for industrial deposits of the type found near the test site in Barberton. The life is at least three years under such conditions and, judging from the apparent rate of deterioration or coating loss, will probably run in excess of five years. This demonstrated performance under one set of conditions justifies at least trial installations of silicone wax on other types of exposure.

Conclusions

Over-insulation in areas subject to heavy contamination has demonstrated effectiveness. To give substantial benefit, the change in size or leakage distance must be gross, on the order of 2 or 3 to 1. Increases in leakage distance on the order of 25 to 30 per cent, for instance, have generally not been of significant benefit. If over-insulation is adopted, standard design insulators are generally preferred because of availability, price, and ease of cleaning. In some cases, the over-insulation has taken the form of structure modification to strain position for local areas of extreme trouble. The strain position arrangement has the triple benefits of improved drip clearance, accessibility of all surfaces for natural cleaning, and the acquisition of sufficient space to allow radical changes in leakage distance.

It is quite possible that our increased technology has produced not only increased contamination but also a beneficial surface coating in silicone wax.

It does not appear that cleaning of one sort or other can be avoided for extreme applications. This might take the form of high pressure, hot-line washing or abrasive blast hot-line cleaning. A more expensive alternate would be hand cleaning in place. Even more expensive would be insulator replacement and complete ground cleaning, although this is done in frequent instances. Natural cleaning through selection of suitable insulator designs is frequently a good solution.

Solid-State Oscillator for Microwave Frequencies

THE first successful operation of a new solid-state device which will oscillate at microwave frequencies recently took place at the Bell Telephone Laboratories, of New York City. The device, which might be called a spin oscillator, will also operate, in principle, as an amplifier. An important characteristic of the new oscillator is that it is expected to have very low noise compared with conventional microwave devices. Thus, in theory, it could considerably extend the range of radio astronomy and could result in altogether new long-distance communication systems to carry television programmes and telephone calls across continents.

The experiment demonstrating the operation of the new device was performed at the Bell Laboratories last November. At that time, Drs. D. Scovil, G. Feher and H. Seidel, the inventors, using a crystal containing a small amount of a paramagnetic salt, produced continuous oscillations at 9000 Mc/s with a power output of about 20 microwatts. Thus, a new source of microwave power operating under new physical principles was demonstrated, and scientists believe that it is only a question of time until microwave amplification can be obtained employing such crystalline materials and operating under the same physical principles as the oscillator. While this experimental result is completely new, the possibility of such an occurrence has been the subject of studies and speculative discussion by a number of physicists for some time. The development is believed to represent the first successful application to a solid-state device of a relatively new principle, which has been called the "maser" principle. "Maser" was first demonstrated applied to molecular beams in gases in 1954 by Professor C. H. Townes and his collaborators at Columbia University. They coined the word "maser," which stands for "microwave amplification by stimulated emission of radiation." Recently there has been increasing interest among physicists, who have been trying to apply the "maser" principle to solids. Combrission, Honig and Townes at the Ecole Normale Superieure in Paris attempted one such application.

The present device, which is still in an early research stage, is expected to have novel and useful characteristics. Because it operates with electron spins in a paramagnetic crystal, theory predicts that it should have very low inherent noise compared with ordinary electronic oscillators or amplifiers which depend on the motion of charged particles at high temperatures. Therefore, it may be possible to amplify wireless signals which may be several hundred times weaker than those usable at present. A potential appears to exist for such microwave devices operating in the centimetre and millimetre wave region, although these experiments on a solid-state device are still in a very early research stage. As an amplifier, it should be moderately broad-band with a bandwidth of the order of 100 Mc/s, and easily tuned since its frequency is proportional to the applied magnetic field. Preliminary theoretical estimates indicate that a noise figure corresponding to thermal noise at perhaps 5 deg. or 10 deg. Kelvin should be attainable. This is hundreds of times better than is now available with conventional microwave circuitry and, if realised in practice, will open a wide application in the microwave field.

The basic operation of this particular solid-state device can be explained by assuming three different energy levels for the unpaired spinning electrons in a paramagnetic crystal lattice in a magnetic field. Normal electron spin states are such that the number in state 1 (lowest energy state) exceeds the number in state 2, which in turn exceeds the number in state 3. By irradiating with sufficient microwave power of the proper frequency, transitions from state 1 to state 3 take place until the populations of these two states are essentially equal corresponding to power saturation. Under these conditions the population of state 2 can be made greater than that of state 1. If a small signal is applied at a frequency corresponding to the energy difference between these two, then stimulated radiative transitions will occur, and power gain will be realised. In the experiment conducted at the Bell Laboratories, the energising frequency was 17,500 M/cs and the signal frequency, which in this case was a self-sustained oscillation, was 9000 Mc/s.

A number of conditions have to be established before such operation can take place. In the first place, a single crystal of a solid-state material having certain specific characteristics is necessary. A whole group of materials, known as "ionically bound paramagnetic salts" appear to be suitable. After a careful survey, gadolinium ethyl sulphate was selected, although it is recognised that other compounds might perform as well or better for specific applications. Secondly, this material has to be diluted with an isomorphous diamagnetic substance to separate the gadolinium atoms sufficiently to reduce electron spin interaction. Lanthanum ethyl sulphate was selected, and it makes up about 99 per cent of the finished crystal. The crystal was mounted in a waveguide cavity having two resonant frequencies, one equal to the frequency of oscillation and one to the frequency of the energising source. The sample occupied about 8 per cent of the cavity volume, and was situated at the point of maximum magnetic field intensity. Low temperature operation is used so that power saturation of the crystal takes place with a reasonable amount of energising oscillator power and also to increase the population difference between the energy levels. The sample and cavity were immersed in liquid helium at reduced pressure which provides a temperature of 1·2 deg. Kelvin.

To produce the necessary separation of the electron spin energy levels, a magnetic field is required. A value of 2800 oersteds was employed in the device built at the Bell Laboratories. This magnetic field may be altered to change the electron spin energies and thus tune the frequency of the stimulated radiation. The field must be properly aligned with respect to the crystal, and can be provided either by a permanent magnet or an electromagnet. The equipment employed at the Bell Laboratories in demonstrating the operation of this new solid-state device included a waveguide cavity, with the crystal in place, immersed in liquid helium. This assembly was placed in the field of a strong electromagnet. The 17,500 Mc/s energising oscillator signal was brought to the cavity through a rectangular waveguide, and the stimulated radiation of 9000 Mc/s was taken away by means of a strip guide mounted inside the rectangular waveguide. The measured power output was about 20 microwatts. The energising oscillator power was about 100 milliwatts to ensure the saturation of the crystal. It is believed that satisfactory operation can be attained with much less power.

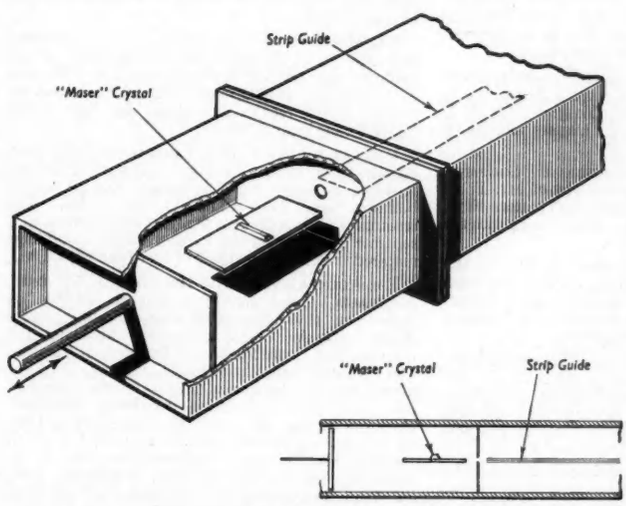


Diagram of resonant cavity "Maser" crystal used in demonstrating new solid-state oscillator for microwave frequencies

Because of the very low noise factor which this device is expected to have an improvement of several hundred times in sensitivity for a microwave receiver is theoretically possible. By using the proper waveguide structure and by using an adequate amount of paramagnetic material, it is expected that sufficient gain can be achieved to realise the advantages of the low noise figure. Although the experiment as carried out at the Bell Laboratories produced oscillations at 9000 Mc/s, operation at both much lower and higher frequencies is possible with a proper choice of solid-state materials and operating conditions. Thus, the solid-state "maser" shows promise of being useful as a pre-amplifier in a wide variety of microwave applications.

Personal and Business

Appointments

MR. BRIAN BAGNALL has been appointed additional London representative of Concrete, Ltd., from April 1, 1957.

MR. S. A. GREGORY, M.I.Chem.E., has been appointed technical manager of Audley Engineering Company, Ltd.

MR. ANGUS MURRAY, A.M.I.Mech.E., has been appointed managing director of the Expert Tool group of companies.

ASSOCIATED BRITISH ENGINEERING, Ltd., has announced the appointment of Mr. J. Peter Ford, A.M.I.E.E., as an executive director.

BUCKLEY AND TAYLOR, Ltd., states that Mr. E. C. Weston has been appointed London manager of its marine and heat exchange division.

MR. J. A. LAMOND, A.M.I.Mech.E., A.M.I.E.E., has been appointed joint managing director of W. H. A. Robertson and Co., Ltd., Bedford.

MR. F. WHITEHEAD, M.I.P.E., has been appointed general manager metal equipment division, at Darlaston and Wrexham, with Rubery, Owen and Co., Ltd.

MR. T. E. MURPHY has been appointed secretary of Harland and Wolff, Ltd., in succession to Mr. George H. Patton who has resigned because of ill health.

THE MARQUESS OF ABERGAVENNY and LIEUT.-GENERAL THE LORD WEEKS have been elected to the board of directors of Massey-Harris-Ferguson, Ltd., Toronto.

DR. DENIS REBBECK has been elected chairman of D. and W. Henderson, Ltd., in succession to the late Sir John Craig and also chairman of A. and J. Inglis, Ltd.

LLOYD'S REGISTER OF SHIPPING has announced that Mr. G. J. Thomas, principal engineer surveyor at Glasgow, has been appointed principal engineer surveyor for Scotland.

THE PLESSEY COMPANY, Ltd., components group, has announced the appointment of Mr. F. C. Loughborough as executive assistant (sales) to the group director, Mr. John A. Clark.

THE CHAMBER OF SHIPPING of the United Kingdom states that at the annual meeting held on February 28, Viscount Simon was elected as president and Mr. Robert D. Ropner as vice-president.

MR. GEORGE WILLIAMS, a senior industrial officer of the Council of Industrial Design, has been appointed design officer to the British Transport Commission. He will take up his new post on May 1.

MR. R. WATKINS has been appointed to represent the Cambridge Instrument Company, Ltd., at 7, Norfolk Court, Norfolk Street, Glasgow. Mr. S. J. Steel will continue to handle all matters relating to repairs and service.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., has announced the appointment of Mr. E. H. Beech as superintendent, foundries and pattern shop, in succession to Mr. A. Phillips, who remains with the company in an advisory capacity.

DR. J. F. C. CONN the chief naval architect to the British Shipbuilding Research Association has been appointed to the John Elder Chair of Naval Architecture at Glasgow University in succession to Professor A. M. Robb who retires in September.

MARCONI INTERNATIONAL MARINE COMMUNICATION COMPANY, Ltd., announces that Mr. G. H. W. Johnson has been placed in charge of the marine business of Marconi (South Africa), Ltd., and will shortly leave for Cape Town to take up his new post.

MR. A. M. SAGE has been appointed manager of the newly formed development department of the British Electro Metallurgical Company. He will continue for a period to be responsible for the British Iron and Steel Research Association's work on structural steels in a consultant capacity.

MR. S. RYMELL has been appointed general manager of Folland Aircraft, Ltd., in succession to Mr. T. Gilbertson. Mr. E. W. Taylor has been appointed deputy general manager in addition to works manager, and Mr. G. Morgan has been appointed acting chief inspector.

THE MINISTRY OF SUPPLY states that with the agreement of the Secretary of State for War, Major-General A. H. Musson has been appointed president of the Ordnance Board, in succession to Air Vice-Marshal J. Marson, and that with the agreement of the Secretary of State for Air, Air Vice-Marshal J. G. Franks has been appointed a vice-president of the Ordnance Board, in succession to Major-General Musson.

H. CLARKE AND CO. (MANCHESTER), Ltd., has announced the following changes in connection with its sales representation: Mr. R. M. King is now responsible for Northamptonshire, Bedfordshire, Cambridgeshire, Norfolk, Suffolk, Essex and Hertfordshire, in addition to sections of the London area. Mr. P. G. Robinson is covering the Birmingham area, Warwickshire, Worcestershire, Staffordshire and Shropshire.

THE INTERNATIONAL HARVESTER COMPANY OF GREAT BRITAIN, Ltd., announces that Mr. Joe F. Ziskal has been appointed manager of engineering in succession to Mr. Ray Birkholz who has been recalled to the U.S.A. to take up new duties. The following appointments as chief product engineers have also been announced; Mr. H. Finne, Bradford tractors; Mr. Roger Clayphan, medium crawler tractors and allied equipment; Mr. Edgar Halstead, engines and Mr. Kennth W. Gerke, assisted by Mr. Charley Bengtsson, special products.

Business Announcements

DOHM, Ltd., states that it is marketing a new plumbago under the name of "Dohmbago."

JOHNSON AND HARTLEY, Ltd., Stockport, states that it has taken over the distribution in Great Britain of A.E.G. high frequency tools.

MR. G. R. CAMPION, sales director of the Coventry Victor Motor Company, Ltd., is leaving on March 17, for a tour of the African continent.

MASSEY-HARRIS-FERGUSON, Ltd., Toronto, has announced the formation of a new company, Massey-Harris-Ferguson do Brazil, S.A., in Sao Paulo.

ROAD MACHINES (DRAYTON), Ltd., states that it is to form a new company in April this year in Vancouver, under the title Muir Robb Equipment, Ltd.

HONEYWELL-BROWN, Ltd., states that its Middlesbrough branch office has moved to 52-60, Fletcher Street, Middlesbrough, (telephone Middlesbrough 44221/3).

ALFRED HERBERT, Ltd., states that it has been appointed sole agent in Great Britain by T. H. and J. Daniels, Ltd., for the Daniels/Latymer vacuum forming machine.

THE CUMMINS ENGINE COMPANY, INC., has announced the establishment of a plant for the manufacture of diesel engines at Shotts, Lanarkshire, Scotland. The new company will be a wholly-owned subsidiary and will be known as Cummins Engine Company, Ltd.

THE MOND NICKEL COMPANY, Ltd., has announced that Mr. L. K. Brindley, deputy chairman of the company and of Henry Wiggin and Co., Ltd., and Mr. A. Parker Hague, a director of the two companies, having reached retirement age, have relinquished their appointments.

HAWKER AIRCRAFT, Ltd., Kingston-upon-Thames, Surrey, is expanding its factory site in Richmond Road and transferring the design office to a new building there from Canbury Park Road. The research and development facilities will be sited in a separate block facing the River Thames: buildings required under the scheme will cost over £1,000,000.

THE AGENT-GENERAL FOR THE STATE OF VICTORIA, AUSTRALIA, states that two English engineering companies have completed manufacturing agreements with Australian companies, involving the investment of English capital in the State of Victoria. The Projectile and Engineering Company, Ltd., has joined with Hardie Trading, Ltd., for the manufacture of "Peco" injection moulding machines. Directors of the new company, Peco-Hardie, Ltd., are Mr. A. J. Chambers, Mr. E. L. Tuff, Mr. G. B. Jackson, Mr. D. McL. Ferguson, and Mr. R. A. Johnson. James Neill and Co. (Sheffield), Ltd., have made an agreement with Patience and Nicholson, Ltd., for the manufacture under licence in Australia of hacksaw blades, which will be marketed by a company to be formed in Melbourne, trading as Eclipse Tools Pty., Ltd. This company will also market other "Eclipse" products manufactured in England. D. G. Bain and Co., Australian agents for James Neill, will become managing agents for "Eclipse" tools.

Contracts

THE SHAW SAVILL LINE announces orders for two refrigerated cargo liners, one from Harland and Wolff, Ltd., Belfast, and the other from Alexander Stephen and Sons, Ltd. Both ships will have the following main particulars; length overall 512ft, breadth moulded 70ft, draught loaded 30ft 3in, gross tonnage 11,000, insulated capacity 393,000 cubic feet. A service speed of 16½ knots will be maintained by a Harland and Wolff, eight-cylinder supercharged diesel engine of 13,300 maximum b.h.p.

ACCLES AND POLLOCK, Ltd., has contracts to supply over 200 miles of tubing, mainly of austenitic stainless steel, to the A.E.I.-John Thompson Nuclear Energy Company, Ltd., and the G.E.C.-Simon-Carves Atomic Energy Group, who are building the nuclear power stations in Gloucestershire and in Scotland respectively. Each reactor will be equipped with "burst slug" detection gear which enables faulty fuel elements to be detected immediately, and removed, so preventing contamination of the reactor and heat exchangers. This detection is effected by taking regular samples of gas from inside the reactors, and the tubes ordered are used for conveying these gas samples to the monitoring instruments. Some of the tubes will be supplied in straight lengths and others manipulated and part fabricated.

METROPOLITAN-VICKERS—G.R.S., Ltd., has a contract worth over £1,000,000 from the Rhodesia Railway Board for the supply and installation of C.T.C. (centralised traffic control) equipment between Kalomo and Ndola, a distance of 439 miles. It covers both C.T.C. supervisory equipment and signalling and interlocking equipment, including searchlight-type signals. It will extend the 122-mile section from Thomson Junction to Zimba, on which similar equipment is to be installed. When it is completed the whole of the main line traffic on about 560 miles of railway will be controlled from four points, Livingstone, Monze, Broken Hill and Ndola, with nearly 100 passing loop sections. Rhodesia Railways will then have 2000 miles of C.T.C.-controlled colour-light signalling—the largest installation in the Commonwealth.

Miscellanea

JET PROPULSION.—The de Havilland Gyron D.Gy. 2, is credited with a thrust of 20,000 lb; 25,000 lb thrust has been achieved with after-burning.

NUCLEAR MACHINERY FOR SUBMARINE.—We are informed by Vickers Nuclear Engineering, Ltd., which consists of Vickers-Armstrongs, Ltd., Rolls-Royce, Ltd., and Foster-Wheeler, Ltd., that good progress has been made in the design and development of nuclear machinery for a submarine. The unit is based on a pressurised water reactor and the prototype will be installed in a land based structure for tests, trials and the training of personnel.

LECTURE IN LONDON BY DOTT. ING. RICCARDO MORANDI.—Dott. Ing. Riccardo Morandi, is visiting this country and at the invitation of the Joint Committee on Structural Concrete, he will present a paper entitled "Modern conceptions in the planning of bridges in reinforced concrete and in prestressed concrete" at the Royal Empire Society, 18, Northumberland Avenue, London, W.C.2. at 6 p.m. on Tuesday March 19. Doctor Morandi has specialised in the design of reinforced and prestressed concrete structures, and is the originator of the system of prestressing which bears his name. His work in bridge design includes the new prestressed "Ponte Amerigo Vespucci" over the Arno at Florence, the new reinforced concrete bridge over the Storms river in South Africa, completed in 1955, and the prestressed "Nueva República" viaduct in Caracas, Venezuela, constructed in 1954. Tickets for the lecture may be obtained on application to The Joint Committee on Structural Concrete, Terminal House, Grosvenor Gardens, London, S.W.1.

MR. FREDERIC HORTON CLOUGH.—We regret to announce that Mr. F. H. Clough, C.B.E., who, until his retirement in 1947, was for many years assistant chief engineer of The British Thomson-Houston Company, Rugby, died on February 25 at the age of 79. He was born at Melbourne, Australia and educated at Geelong Grammar School. After serving a two-year apprenticeship with the Austral Otis Engineering Company, Melbourne, he joined Siemens Brothers of Woolwich, and worked in the drawing-office, test department and in the erection shops. In the meantime he studied at Finsbury Technical College, King's College, and Owen's College. In 1901 he went to Germany and worked on experimental testing with Siemens and Halske, Berlin, and in 1902 he joined B.T.H. at Rugby in the design department, and later became responsible for the design of turbo-alternators. For a time during World War I he was technical adviser to the Director of Torpedo and Mining at the Admiralty, and for his services was awarded the C.B.E. He became assistant chief engineer at B.T.H. in 1919—a position he held until his retirement. Mr. Clough was a member of the Institution of Civil Engineers and the Institution of Electrical Engineers; he served as chairman of the I.E.E. Midland Centre, and on the I.E.E. Council in London.

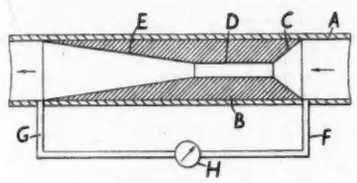
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

MEASURING APPARATUS

767,337. August 25, 1954.—THE MEASUREMENT OF THE WETNESS OF STEAM, C.U.R.A. Patents, Ltd., Randalls Road, Leatherhead, Surrey. (*Inventors: Alex David Chalmers Gunn and Neil Marshall.*)

The invention relates to the measurement of the wetness of steam flowing in a conduit. The drawing shows, in side elevation, a venturi located in a steam supply conduit. A steam generating and/or steam utilising system includes a steam supply conduit *A* in which there is located a venturi indicated generally at *B* and having an entrance cone *C*, a throat *D* and an exit cone *E*. Pressure tappings *F* and *G* located respectively immediately upstream of the entrance cone *C* of the venturi and immediately downstream of the exit cone *E* of the venturi lead to a differential pressure gauge shown diagrammatically *H*. A flow meter comprising an orifice plate situated in the conduit *A* and a differential pressure gauge connected to pressure tappings located one on each side of the plate is situated on either the upstream or the downstream side of the venturi. Any other form



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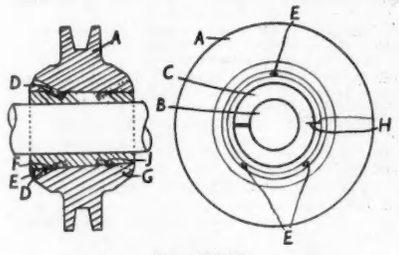
of flow meter which is affected by the wetness of the steam differently from a meter employing a venturi may be used. The operation is performed as follows. The apparatus is first calibrated by passing steam, of which the wetness is known, through it and measuring the rate of flow by means of the flow meter and the pressure drop across the venturi *B* by means of the differential pressure gauge *H*. This is done for a number of different values of the wetness and the rate of flow. From the results so obtained curves may be plotted which enable the wetness of steam flowing along the conduit to be obtained at once from the reading of the flow meter and the differential pressure gauge.—*January* 30, 1957.

POWER TRANSMISSION

768,466. November 29, 1954.—MEANS FOR SECURING PULLEYS AND WHEELS ON SHAFTS, John Reucassel, 33, Belvedere Road, Salisbury, Southern Rhodesia.

Referring to the drawing, it will be seen that the pulley *A* is fixed to the shaft *B* by means of a tapered split bush *C* in such a way that screws *D* are turned against the outer surface of the bush. The holes *E* for the screws are arranged inside the body of the pulley at an angle, so that by turning the screws



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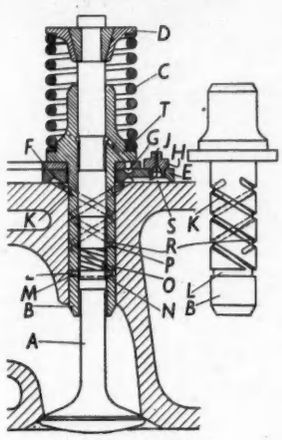
against the bush it is effectively pressed into the pulley. The screws press against the surfaces of recesses *F* on the outer surface of the bush. The recesses are so deep that once the screw end is in the recess the bush cannot change its position sidewise inside the pulley. If the bush is to be removed, screws *D* are turned in the opposite direction so that they do not press against the recesses *F* and the pulley can be readily knocked off the tapered bush. In order to facilitate the removal of the bush, if required, further holes for screws *G* can be arranged at an angle to press against the bush in the direction opposite to that of screws *D*. Instead of a number of recesses, one or more annular grooves may be provided on the outer surface of the bush. Markings *H* on either ends of bush and pulley must be in alignment when the bush is pressed into the pulley in order to bring screws and recesses into alignment.—*February* 20, 1957.

INTERNAL COMBUSTION ENGINES

768,502. April 7, 1955.—VALVE ASSEMBLIES, Sulzer Frères, Société Anonyme, Winterthur, Switzerland.

The invention relates to valve assemblies for internal combustion engines and is applicable more particularly, but not exclusively, to exhaust valve assemblies. In a valve assembly according to the present invention there is a path adjacent the valve stem for the conveyance of sealing and cooling air, beginning at an annular channel surrounding the stem and leading away from the valve head towards a constriction. In the arrangement shown in the drawing the valve stem *A* slides in a guide *B*, and is held in its closed position by a spring *C* which bears against a cap *D*. In a member *E* common to all the engine valves there are disposed an inlet passage *F* for the sealing and cooling air, an inlet passage *G* for the lubricant, and a replaceable fitting *H* with a calibrated



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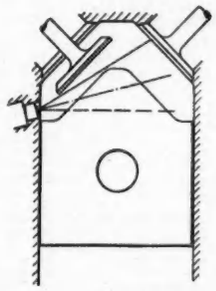
constriction *J*. Alternatively, the constriction may be an adjustable one so that the resistance can be varied. The air, which is under a pressure of approximately 0·3 to 0·4 atmospheres above atmospheric pressure, passes from the inlet passage *F* into a helical groove *K* around the outside of the valve guide *B* and is led thereby into an annular channel *L* connected through holes *M* with an annular channel *N* around the valve stem. The air then flows upwards through a path constituted by helical grooves *O* in the valve stem, and passes out through a hole *P* into a second helical groove *R* around the outside of the guide. From this groove the air passes into a passage *S* in the member *E*, and then escapes through the constriction *J*. Any lubricant which has been delivered to the valve stem through the lubricant inlet passage *G* and a bore *T* and has run down as far as the helical grooves *O*, is carried along by the air through the constriction *J* into the valve chamber, whence it escapes into an oil collector. A modified construction is also shown in the specification.—*February* 20, 1957.

768,425. April 18, 1955.—INJECTION-TYPE INTERNAL COMBUSTION ENGINES, The Daimler-Benz Aktiengesellschaft, of Stuttgart-Untertürkheim, Germany.

The invention concerns improvements relating to mixture-compressing injection-type internal combustion engines. In such an engine, the discs of overhead poppet valves are inclined so as to form with a ridge-shaped piston crown, a combustion chamber which has a cross-section of inverted V-shape in at



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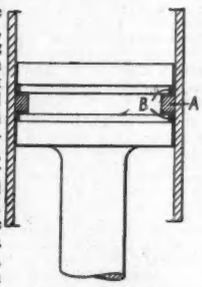
least a plane containing the valve stems. The injection nozzle, which opens in the region of the piston track in the cylinder, is uncovered by the upper edge of the piston during the first half of the suction stroke. This nozzle is arranged so that the fuel is sprayed against the exhaust valve opposite and so that, at least at the beginning of the injection period, most of the fuel impinges upon and is reflected by a ridge surface of the piston crown. By this arrangement, the hot piston crown and, if desired, the hot exhaust valve, are cooled by fuel sprayed thereon on account both of its low temperature and its latent heat of vaporisation. In addition, the fuel is prepared thermally by the heat and mechanically by impact. Despite its impact on a relatively large area of the piston, the fuel jet is concentrated, by the reflection, towards the upper part of the combustion chamber where it is subjected to a stream of fresh air, entering substantially transversely of the direction of fuel movement, immediately after the entry of the air into the chamber. The combustion air is therefore intimately mixed from the start with fuel which has already been prepared.—*February* 13, 1957.

757,858. October 8, 1954.—FLUID PRESSURE SEALING MEANS FOR PISTONS, Short Brothers and Harland Ltd., Seaplane Works, Queens Island, Belfast. (*Inventor: Hugh Graham Conway.*)

The invention relates to the means which are employed to effect a fluid pressure seal between a reciprocating piston and its cylinder, the object being to provide an improved form of sealing means, by which wear of the working surfaces will be minimised. A fluid pressure seal is maintained between the piston and the cylinder, by a continuous sealing ring, comprising an annulus *A* of resilient material such as natural or synthetic rubber, and two continuous anti-friction rings *B*, of bronze, synthetic resin, or other plastic material. If desired these rings may be coated with white metal. The ring *A* is received in a deep groove in the piston, and the rings *B* are in shallower grooves on either side. The arrangement is such that in addition to providing bearing surfaces for the piston the rings *B* also support the ring *A* against lateral deflection. More than one such assembly of sealing and anti-friction rings may be fitted, a separate set of grooves being provided for their retention.—*February* 6, 1957.



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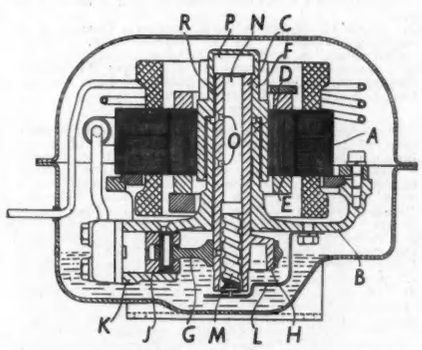
BLOWERS AND COMPRESSORS

768,058. February 16, 1955.—LUBRICATING DEVICE FOR A MOTOR-DRIVEN AIR COMPRESSOR, Heinz Teves and Ernst August Teves, trading as Alfred Teves Maschinen- und Armaturenfabrik K.G., 41-53, Rebstöcker Strasse, Frankfurt/Main, Germany.

As illustrated in the drawing, the stator *A* is attached to the bearing body *B*. The crankshaft *C* is also supported in the bearing member *D*, the rotor of the motor being arranged on the shaft over the carrier *F*. The connecting rod *G* on the eccentric of the crankshaft *H*, reciprocates a piston *J*, in the cylinder *K*. The crankshaft is hollow, and its lower



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end projects into the oil sump of the equipment. A retainer *L* holds an oil feed worm *M*, on the bearing body, the worm projecting into the lower end of the hollow shaft *C*. Above the oil feed worm, the shaft is designed as an oil storage space *N*, for the oil conveyed by the oil feed worm, the oil being led either by radial bores *O* to the bearings, or instead of the radial bores, the oil can be led by an enclosed chamber *P* and longitudinal grooves *R* in the rotor carrier *F*, and the bearing member *D*. The avoidance in accordance with the invention of spiral rotating oil grooves at the places to be lubricated results in constant oil pressure at the bearing surfaces.—*February* 13, 1957.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Wed., March 13.—BIRMINGHAM BRANCH : Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Earth Leakage Protection in Domestic and Similar Installations," E. Coleman, 7.15 p.m. ★ BRADFORD BRANCH : Bradford Royal Infirmary, Bradford, "Uses of 'X' Rays," P. Hudson, 8 p.m.

Thurs., March 14.—PORTSMOUTH BRANCH : Royal Beach Hotel, Southsea, "Co-ordination between Lighting and Interior Decoration in Industry," Raymond Pye, 8 p.m.

Sat., March 16.—OXFORD, READING AND DISTRICTS BRANCH : Regents Park College, Pusey Street, Oxford, "Specialised Spot Welding," C. G. Aldridge, 6.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., March 13.—N.E. SECTION : Institution of Mining and Electrical Engineers, Neville Hall, Westgate Road, Newcastle upon Tyne, "Basic Waveguide Test Appliances," R. C. Tomkinson, 6 p.m.

Fri., March 15.—SCOTTISH SECTION : Department of Natural Philosophy, University of Edinburgh, "Applications of Particle Accelerators," C. W. Miller, 7 p.m.

CHEMICAL SOCIETY

Thurs., March 14.—Royal Institution, Albemarle Street, London, W.1, "Chemical Problems Relating to the Origin of the Earth," H. C. Urey, 7.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., March 13.—LONDON SECTION : Kingsley Hotel, Bloomsbury Way, London, W.C.1, "Comparison of Conventional Space Heating Systems," J. R. Kell, 10.30 a.m., and "Space Heating by Direct Combustion," F. J. Strong, 2.30 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Mon., March 11.—Spencer Arms, Hull, Film, "Building in General," A. Potter, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., March 11.—SHEFFIELD CENTRE : Medical Library, The University, Western Bank, Sheffield, "Light and Vision," H. Moore, 6.30 p.m.

Tues., March 12.—Federation of British Industries, 21, Tothill Street, London, S.W.1, "Visibility on the Road," A. J. Harris, 6 p.m. ★ BATH AND BRISTOL CENTRE : Royal Hotel, Bristol, "A Critical Analysis of Lighting Equipment and its Maintenance," J. Mortimer Hawkins and C. J. Veness, 3 p.m.

Fri., March 15.—LEEDS CENTRE : Yorkshire Electricity Board, Ferensway, Hull, Annual General Meeting, 7 p.m.

INCORPORATED PLANT ENGINEERS

Mon., March 11.—MERSEYSIDE AND N. WALES BRANCH : Exchange Hotel, Liverpool, Annual General Meeting, 7.15 p.m.

Tues., March 12.—MANCHESTER BRANCH : Engineers' Club, Albert Square, Manchester, Annual General Meeting, 7.15 p.m.

Thurs., March 14.—N.E. BRANCH : Roadway House, Oxford Street, Newcastle upon Tyne, "Coal and its Handling," R. H. Furness, 7 p.m. ★ PETERBOROUGH BRANCH : White Lion Hotel, Church Street, Peterborough, Annual General Meeting, 7.30 p.m.

INSTITUTE OF FUEL

Wed., March 13.—Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "The Work of B.C.U.R.A., on the Coking Stoker," M. V. Murray, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., March 12.—85, Minories, London, E.C.3, "The Harland and Wolff Pressure Charged Two-Stroke Single-Acting Engine," C. C. Pounder, 5.30 p.m.

Wed., March 13.—SCOTTISH SECTION : Grosvenor Hotel, Edinburgh, "The Wire Mill," R. Taylor, 7.30 p.m.

Thurs., March 14.—N.E. COAST SECTION : Stephenson Building, King's College, Claremont Road, Newcastle upon Tyne, "Combating Cylinder Wear and Fouling in Large Low-Speed Diesel Engines," M. J. van der Zijden and A. A. Kelly, 6.15 p.m. ★ S. WALES SECTION : S. Wales Institute of Engineers, Park Place, Cardiff, Joint Meeting with the Institute of Welding, "Welding in Marine Engineering," J. A. Dorrat, 7 p.m.

Fri., March 15.—SCOTTISH SECTION : Robert Gordon's College, Aberdeen, "The Wire Mill," R. Taylor, 7.30 p.m.

INSTITUTE OF METALS

Mon., March 11.—SCOTTISH LOCAL SECTION : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Production and Uses of Rare Metals," J. C. Chaston, 6.30 p.m.

Tues., March 12.—S. WALES LOCAL SECTION : Department of Metallurgy, University College, Singleton Park, Swansea, "Clad Metals," A. R. E. Singer, 6.45 p.m.

Thurs., March 14.—BIRMINGHAM LOCAL SECTION : Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, Annual General Meeting, 6.30 p.m.

INSTITUTE OF PHYSICS

To-day, March 8.—LIVERPOOL AND N. WALES BRANCH : Department of Electrical Engineering, University of Liverpool, Brownlow Street, Liverpool, "Pion Physics," J. M. Cassels, 7 p.m. ★ MANCHESTER AND DISTRICT BRANCH : Bragg Building, University of Manchester, "Some Aspects of Vision," R. A. Weale, 6.45 p.m. ★ S. WALES BRANCH : University College of Swansea, Swansea, "The Recording of Faint Optical Images," J. D. McGee, 5.15 p.m.

Mon., March 11.—SCOTTISH BRANCH : Natural Philosophy Department, University of Edinburgh, "The Velocity of Light—A Survey of the Measurement Technique," L. Essen, 7.15 p.m.

Tues., March 12.—SCOTTISH BRANCH : Natural Philosophy Department, University of Glasgow, "The Velocity of Light—A Survey of the Measurement Technique," L. Essen, 7.15 p.m.

Wed., March 13.—YORKSHIRE BRANCH : University of Sheffield, "The Properties of Materials in Nuclear Reactors," P. Murray, 5 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

To-day, March 8.—S. WALES GROUP : S. Wales Institute of Engineers, Park Place, Cardiff, "From the Laboratory to the Road," W. A. Snell, 7 p.m.

Mon., March 11.—E. REGIONAL CENTRE : Houldsworth Hall, 90, Deansgate, Manchester, "Petrol Injection," J. N. Morris, 7.30 p.m.

Tues., March 12.—MIDLANDS CENTRE : Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Gas Turbine Development for Road Transport," P. A. Phillips, 7.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Mon., March 11.—N. CENTRE : N.E. Electricity Board, Carliol House, Newcastle, "Farming in the Sudan," J. L. Manson, 6.45 p.m.

Tues., March 12.—LONDON MEETING : 6, Buckingham Gate, London, S.W.1, "Slip Clutches and Mechanical Safety Devices," F. Lee, 5 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Thurs., March 14.—N.W. BRANCH : Reynolds Hall, College of Technology, Manchester, "Disposal of Long-Lived Fission Products," J. R. Grover, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., March 12.—RAILWAY (B) MEETING : Great George Street, Westminster, London, S.W.1, "Site and Laboratory Work in connection with the Development of Long Welded Rail Track on the Western Region of British Railways," K. D. Rhodes and M. R. Dart, 5.30 p.m.

Thurs., March 14.—YORKSHIRE ASSOCIATION : Chemistry Lecture Theatre, Leeds University, Joint Meeting with Yorkshire Branch of the Institution of Mechanical Engineers, "Pumping Problems—Present and Future," H. Addison, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., March 11.—EDUCATION DISCUSSION CIRCLE : Savoy Place, London, W.C.2, Discussion on "Simple Approaches to the Understanding of Commutation," opened by A. Tustin, 6 p.m. ★ LONDON GRADUATE AND STUDENT SECTION : Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, Joint Meeting with the Institutions of Civil and Mechanical Engineers, "Power Resources," J. Eccles, 6.30 p.m. ★ MALVERN AND DISTRICT GROUP : Winter Gardens, Malvern, "Vacuum Techniques," D. J. Taylor; "Temperature Control," J. P. King; "Cutting of Semi-Conductors," J. R. Walford, 7.30 p.m. ★ N.E. CENTRE : Neville Hall, Newcastle upon Tyne, "Mechanical Strength of Power Transformers in Service," E. T. Norris, 6.15 p.m. ★ S. MIDLAND SUPPLY AND UTILIZATION GROUP : Imperial Hotel, Birmingham, "Age and the Incidence of Fires in Electrical Installations," L. Gosland, 6 p.m. ★ W. CENTRE : S. Wales Institute of Engineers, Park Place, Cardiff, "Transistor Power Amplifiers," R. A. Hilbourne and D. D. Jones; "Transister D.C. Convertors," L. H. Light and P. M. Hooker, 6 p.m.

Tues., March 12.—MEASUREMENT AND SUPPLY SECTION : Savoy Place, London, W.C.2, in conjunction with the British Nuclear Energy Conference, "An Analogue Computer for Nuclear Power Studies," and "The Application of Analogue Methods to Compute and Predict Xenon Poisoning in a High-Flux Nuclear Reactor," G. J. R. MacLusky, 5.30 p.m. ★ LONDON GRADUATE AND STUDENT SECTION : R.E.M.E. Training Centre, Bailleul Barracks, Arborfield, Berkshire, "The Gyroscope," H. W. Thomas, 7 p.m. ★ N. IRELAND CENTRE : Engineering Department, Queen's University, Belfast, "The Potentialities of Railway Electrification at the Standard Frequency," E. L. E. Wheatcroft and H. C. C. Barton, 6.30 p.m.

Wed., March 13.—LONDON GRADUATE AND STUDENT SECTION : Visit to Lime Grove Television Studios, 2.30 p.m. ★ N. SCOTLAND SUB-CENTRE : Caledonian Hotel, Aberdeen, "Automatic Circuit breakers," G. F. Peirson, A. H. Pollard and N. Carl, 7.30 p.m. ★ N.W. RADIO AND TELECOMMUNICATION GROUP : Engineers' Club, Albert Square, Manchester. "The Electronic Age," R. C. G. Williams, 6.45 p.m. ★ N. LANCASHIRE SUB-CENTRE : N.W. Electricity Board, 19, Friargate, Preston. "The Potentialities of Railway Electrification at the Standard Frequency," E. L. E. Wheatcroft and H. C. C. Barton, 7.15 p.m. ★ OXFORD DISTRICT MEETING : S. Electricity Board, 37, Geroge Street, Oxford, "Impulse Testing of Electrical Equipment for Supply Systems," D. Wadland, 7 p.m.

Thurs., March 14.—UTILIZATION SECTION : Savoy Place, London, W.C.2, "Electrical Equipment for Rectifier Locomotives," H. B. Calverley, E. A. Jarvis and E. Williams, and "Circuit Calculations for Rectifier Locomotives and Motor Coaches," T. E. Calverley and D. G. Taylor, 5 p.m. ★ N. SCOTLAND SUB-CENTRE : Electrical Engineering Department, Queen's College, Dundee, "Automatic Circuit Breakers," G. F. Peirson, A. H. Pollard and N. Carl, 7 p.m. ★ E. MIDLAND CENTRE : George Hotel, Kettering, "Research in Industry," D. R. Hardy, 7.30 p.m. ★ W. WALES SUB-CENTRE : S. Wales Electricity Board, Kingsway, Swansea, "Highland Water Power—The Developments of the North of Scotland Hydro-Electric Board," A. A. Fulton, 6 p.m.

Fri., March 15.—N.E. GRADUATE AND STUDENT SECTION : Grey Hall, King's College, Newcastle upon Tyne, "Electricity as an Aid to Coal Mining," R. Quayle and R. Strong, 6.30 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Mon., March 11.—N.E. BRANCH : Northern Architectural Association Hall, 6, Higham Place, Newcastle upon Tyne, "The Automatic Control of Gear Production Machine Tools," J. A. Mills, 7.15 p.m.

INSTITUTION OF ENGINEERS-IN-CHARGE

Wed., March 13.—St. Bride Institute, Bride Lane, Fleet Street, London, E.C.4, "Atomic Energy," J. A. Dixon, 6 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Tues., March 12.—39, Elmbank Crescent, Glasgow, "Ship Repairing," D. H. Sword, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Wed., March 13.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Some Design Considerations of Floor Heating," E. Danter, 6 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Thurs., March 14.—UTILIZATION SECTION : Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Electrical Equipment for Rectifier Locomotives," H. B. Calverley, E. A. Jarvis and E. Williams, and "Circuit Calculation for Rectifier Locomotives and Motor Coaches," T. E. Calverley and D. G. Taylor, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, March 8.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Market Research and the Engineer," 6.45 p.m.

Mon., March 11.—LUTON A.D. CENTRE : Assembly Room, Luton Town Hall, Luton, "A Review of Hydrokinetic Fluid Drives and their Possibilities for the British Motor Industry," J. G. Giles, 7.30 p.m. ★ LONDON GRADUATES' SECTIONS : 1, Birdcage Walk, Westminster, London, S.W.1, Joint Meeting the Institutions of Civil and Electrical Engineers, "Sources of Power," Sir Josiah Eccles, 6.30 p.m.

Tues., March 12.—AUTOMOBILE DIVISION : 1, Birdcage Walk, Westminster, London, S.W.1, General Meeting, "Transmission Developments for Public Service and Heavy Goods Vehicles," A. Gordon Wilson, 6 p.m. ★ S. WALES BRANCH : King's Head Hotel, Newport, Monmouthshire, "Application of Digital Computers to Machine Tool Operation," 6.30 p.m.

Wed., March 13.—E. MIDLANDS BRANCH : Technical College, Lincoln, "The Influence of the Gas Turbine Axial Flow Aero-Engine on Blade Manufacturing Methods," R. R. Whyte, 7.30 p.m. ★ SCOTTISH GRADUATE SECTION : Room 24, Royal College of Science and Technology, Glasgow, "Diesel Traction on British Railways," R. E. Gregory, 7.30 p.m.

Thurs., March 14.—E. BRANCH : Assembly House, Norwich, "The U.K. Atomic Energy Project," J. V. Danworth, 7.30 p.m. ★ N.W. BRANCH : Engineers' Club, Albert Square, Manchester, "Fast Reactor," J. Tatlock, 6.45 p.m. ★ YORKSHIRE BRANCH : Leeds University, Chemistry Lecture Theatre, Leeds, Joint Meeting with the Institution of Civil Engineers, "Pumping Problems : Present and Future," H. Addison, 6.30 p.m. ★ E. MIDLANDS GRADUATE SECTION : College of Technology, Loughborough, Film Show, 7.15 p.m. ★ LONDON GRADUATE SECTION : 1, Birdcage Walk, Westminster, London, S.W.1, "The Development of a New Automobile," P. Heckman and E. Boden, 6.30 p.m. ★ YORKSHIRE GRADUATE SECTION : Visit to Briggs Motor Bodies, Ltd., Doncaster, 2 p.m.

Fri., March 15.—LUBRICATION GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Factors in the Handling of Lubricants," 6.45 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, March 8.—E. COUNTIES BRANCH : Britannia Works, Davey, Paxman and Co., Ltd., Colchester, "Trade Unions and Productivity," L. Stubbs, 7 p.m.

Mon., March 11.—YORKSHIRE BRANCH : Hotel Metropole, Leeds, "Lubrication in all its Aspects," G. E. T. Eyston, 7.15 p.m.

Tues., March 12.—LONDON GRADUATE BRANCH : 10, Chesterfield Street, London, W.1, Annual General Meeting, 7.15 p.m. ★ BIRMINGHAM GRADUATE BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting, 6.30 p.m.

Wed., March 13.—HALIFAX GRADUATE BRANCH : White Swan Hotel, Halifax, "Applied Motion Studies," H. Wilkinson, 7.30 p.m. ★ DUNDEE BRANCH : Technical College, Bell Street, Dundee, Annual General Meeting, 7.30 p.m. ★ EDINBURGH BRANCH : North British Hotel, Princes Street, Edinburgh, "The Implications of Automation," 7.30 p.m. ★ PRESTON BRANCH : Crown Hotel, Victoria Street, Blackburn, "Varied Application of Drilling Machines in Relation to Production," W. A. Hannaby, 7.30 p.m. ★ LIVERPOOL BRANCH : Radiant House, Bold Street, Liverpool, "Ultrasonic Machining of Hard Materials," C. F. Brocklesby, 7.30 p.m. ★ NOTTINGHAM BRANCH : Victoria Station Hotel, Milton Street, Nottingham, Annual General Meeting, 7 p.m.

Thurs., March 14.—LEICESTER BRANCH : Grand Hotel, Leicester, "Pride in Craftsmanship: To-day's Challenge," Sir Gordon Russell, 7 p.m. ★ ROCHESTER BRANCH : Sun Hotel, High Street, Chatham, "Full Employment Incentives and Productivity," J. Ayres, 7.30 p.m.

Fri., March 15.—WEST WALES BRANCH : Central Library, Alexandra Road, Swansea, "Lithographic Printing," 7.30 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., March 11.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, "Microscopy of Rubber," C. H. Leigh-Dugmore, 6.45 p.m. ★ PRESTON SECTION : Bull and Royal Hotel, Church Street, Preston, "Practical Application of Slush Moulding and Plastisol," S. Mottram, 7.15 p.m. ★ S. WALES AND MONMOUTHSHIRE SECTION : Angel Hotel, Cardiff, "Extruders and Extrusion," A. Crowther and Mr. Robinson, 7.30 p.m.

Tues., March 12.—LONDON SECTION : Royal Society of Tropical Medicine and Hygiene, 26, Portland Place, London, W.1, "Petroleum as a United Kingdom Source of Raw Material for Synthetic Rubber," A. A. Appleton, 5.30 p.m., and Fluorinated Elastomers," M. Stacey, 7 p.m.

Wed., March 13.—W. OF ENGLAND SECTION : Royal York Hotel, George Street, Bath, "Polyesters and Isocyanates in the Rubber and Plastics Industries," J. T. Watts, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Wed., March 13.—MIDLAND COUNTIES BRANCH : Becket Sale Room, Derby, "Revisions to CP.114 (1948)," Walter C. Andrews, 6.15 p.m.

Thurs., March 14.—11, Upper Belgrave Street, London, S.W.1, "Structural Problems Connected with Palletisation," B. Scruby, 6 p.m.

IRON AND STEEL INSTITUTE

Mon. to Thurs., March 11 *to* 14.—IRON AND STEEL ENGINEERS' GROUP : Meeting of Junior Engineers in Chester and Manchester.

JUNIOR INSTITUTION OF ENGINEERS

To-day, March 8.—ORDINARY MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Treatment of Effluents," A. H. Waddington, 7 p.m.

Mon., March 11.—SHEFFIELD AND DISTRICT SECTION : Livesey Clegg House, Union Street, Sheffield, "Reflections of Forty Years in the Steel Industry," F. A. Hurst, 7.30 p.m. ★ N.W. SECTION : Engineers' Club, Albert Square, Manchester, Film Evening, 7.30 p.m.

Fri., March 15.—INFORMAL MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Astronautics To-day and Tomorrow," G. V. E. Thompson, 7 p.m.

LIVERPOOL ENGINEERING SOCIETY

Wed., March 13.—INFORMAL MEETING : 9, The Temple, 24, Dale Street, Liverpool, "Modern Roadways," R. S. Benson, 6 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., March 15.—Engineers' Club, Albert Square, Manchester, "Industrial Television," J. E. H. Brace, 6.45 p.m.

NEWCOMEN SOCIETY

Wed., March 13.—ORDINARY GENERAL MEETING : Lecture Theatre, Science Museum, South Kensington, London, S.W.7, "F. W. Lanchester, LL.D., F.R.S.: His Life and Work," George H. Lanchester, 5.30 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Mon., March 11.—Literary and Philosophical Society, Newcastle upon Tyne, "The Stork Engine," A. Hootsen, 6.15 p.m.

OLD CENTRALIANS

Thurs., March 14.—Constitutional Club, Northumberland Avenue, London, W.C.2, "The Scope and Practice of Engineering in the Chemical Industry," H. Fossett, 12.45 p.m.

REINFORCED CONCRETE ASSOCIATION

Wed., March 13.—11, Upper Belgrave Street, London, S.W.1, Reinforced Concrete Problems on the Gold Coast," F. S. B. Jacobson, 5.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., March 12.—SECTION LECTURE : 4, Hamilton Place, London, W.1, "High-Temperature Materials for Engines," E. R. Gadd, 7 p.m.

ROYAL SOCIETY OF HEALTH

Wed., March 13.—LONDON SESSIONAL MEETING : 90, Buckingham Palace Road, London, S.W.1, "The Treatment of Trade Effluents : A General Survey," A. E. J. Pettet, 2.30 p.m.

Thurs., March 14.—BOLTON SESSIONAL MEETING : Town Hall, Bolton, "Practical Experience of Smoke Control, with particular reference to the Clean Air Act, 1956," T. Williams, L. Shufflebotham, G. Gill and S. N. Duguid, 10 a.m.

ROYAL STATISTICAL SOCIETY

Mon., March 11.—S. WALES GROUP : University College, Cardiff, "Electronic Computers for Industrial Statistical Problems," D. G. Owen, 6.30 p.m.

Wed., March 13.—N.E. GROUP : Armstrong Building, King's College, Newcastle upon Tyne, "The Accuracy of Statistics Calculated from Non-Random Series, with special reference to Industrial Applications," G. H. Jowett, 6.30 p.m.

SOCIETY OF THE CHEMICAL INDUSTRY

Mon., March 11.—14, Belgrave Square, London, S.W.1, "A Survey of Industrial Filtration," A. P. Hosking and K. C. Salter, 5.30 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

Fri., March 15.—39, Elmbank Crescent, Glasgow, Joint Meeting with the Iron and Steel Engineers' Group, "A Review of Some Rolling Mill Engineering Practices," F. G. Thomson, 6.45 p.m.